Broad Brushes & Useful Approximations: Measuring Urban Form in Location Affordability Research

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Abstract

Scholars use a variety of methods to measure the size, shape, configuration, and characteristics of cities in analyzing the causes and consequences of urban form. The diversity of measurement approaches is a reflection of the vast range of research questions involving urban form and of various disciplinary traditions. The methodological variation is also a consequence of the complexity and diversity of urban systems themselves, which complicates the work of identifying and measuring the dimensions of interest.

One area of research that can benefit from including urban form is analyses of location affordability (LA). LA is the joint consideration of housing and transportation costs, recognizing that these constitute the most important household cost burdens, especially for lower income households. From an LA perspective, understanding affordability requires understanding both housing cost burdens and transportation costs burdens that are associated with a given location choice. Because housing and transportation are important elements of the patterns and characteristics of urban systems, the spatial configuration of these two systems can be an important factor in shaping household cost burdens. Thus the consequences of urban form are of interest to LA researchers and those who work in the housing and transportation sectors.

This paper presents a systematic review of recently published scholarly articles that describe measures of urban form along with articles that link urban form with housing and/or transportation affordability. Measurement methods are categorized by the scale of measurement, types of metrics, and whether urban form serves as a predictor of the outcome of interest or is itself the result. The review finds urban form associated with research in a wide range of disciplines and research questions. There is a greater use of multiple metrics than single metrics, with long-accepted measures of density and spatial configuration frequently combined with other types of measures. The review provides an overview of recent trends in methods that are relevant for the emerging LA research and policy community.

Introduction

While housing affordability has long been of interest to scholars, in recent years the emerging concept of location affordability (LA) has gained some attention. LA expands on housing affordability by explicitly including the transportation cost burdens that are incurred by a location choice. In the U.S., housing is considered affordable if it claims no more than 30% of household income. This definition is used for allocating housing subsidies, identifying distressed neighborhoods, and in scholarly research on economic stresses. However, this approach does not consider transportation expenses, which constitute the second-largest budget category of the average U.S. household. Thus from an LA perspective, understanding affordability requires jointly considering both housing cost burdens and the transportation costs associated with a given location choice. The concept offers a fuller picture of household cost burdens and can inform cross-sectoral and multi-pronged policies and programs that may be more effective in addressing the needs of lower income households than housing-alone strategies.

Because both housing and transportation are important components of an urban system, urban form—defined as the spatial patterns and spatial characteristics of human settlements—are often included as a factor in analyses of housing affordability, transportation affordability, and location affordability.

Scholars use a variety of methods to measure the size, shape, configuration, and characteristics of cities in analyzing the effects of urban form. The approach to measurement is shaped by the particular research questions, hypothesized relationships, and theories of causality. Other considerations include the scale of the analysis, the geographical setting, available data sources, and conventions within a scholarly discipline. Further, more and more spatial data are available, with ever-improving resolution, to which scholars can apply increasingly sophisticated visualization and analytic techniques, all of which greatly expands the options for representing urban form in research.

To provide insight into the current state of the practice in measurement and analysis, this working paper presents a systematic review of recently published research that includes urban form measures in studies that also address housing and/or transportation affordability. The review describes where such studies are being published and the methods and metrics of measuring urban form being used by scholars.

Method and Materials

Because the focus of this review is current methods of representing urban form in connection with location affordability, the search for published research was restricted to the years 2006 through 2016. It was 2006 when the highly influential Housing + Transportation (H+T) Index was first published, making the case for LA as an issue for the U.S. policy agenda (The Center for Neighborhood Technology and The Center for Transit-Oriented Development, 2006). The H+T Index applied thresholds of household cost burdens for housing and transportation and displayed these costs jointly for 42 U.S. metropolitan regions. The project captured the attention of scholars, practitioners and decision makers, drawing attention to the need to re-evaluate policy, practice, and research and arguing for explicitly considering the linkage between these two sectors and their joint impact on economic well-being of lower income households.

The Social Sciences Citation Index (Web of Science, Thompson Reuters) was used to search their 'Core Collection' for published articles. This database includes the Social Citation Index Expanded (8,300 journals, 150 disciplines), the Social Sciences Citation Index (over 2,900 journals across 50 social sciences disciplines), the Arts & Humanities Citation Index (over 1,600 journals), and the Emerging Sources Citation Index (covers relatively new journals that are not yet indexed in the other indices; from 2015 to the present). The searches were carried out in late February and early March of 2016.

As LA is cross-disciplinary concept, various search terms were used in anticipation of inconsistent terminology among disciplines. Table 1 provides the search strategy, which returned a total of 104 articles. Initial screening reduced the number of articles to 86 (two articles on location tracking technologies for wildlife research were removed for relevancy, several articles were duplicates returned by more than one search).

Table 1: Article Search Strategy

Initial search terms	*'urban index'*	*'measuring urban sprawl'*	*'location affordability'*	*'housing affordability'*	*'affordability'*
Initial articles returned	9,946	385	106	483	2,394
		Categories retained: • architecture • economics • engineering civil • geography • multidisciplinary sciences • planning development • social sciences interdisciplinary • transportation • transportation science technology • urban studies			
Filtered articles	1,506	181	**50**	339	569
Initial search refined by '*housing*' + '*transport**'	**9**	**8**	--	--	**19**
Initial search refined by '*sprawl*'	--	**--**	**--**	**10**	--
Initial search refined by '*urban form*'	--	**--**	**--**	**8**	--
Articles included	**9**	**8**	**50**	**18**	**19**

Results

Further screening reduced the number of articles to 75 by removing articles that were discussions of plans or policies without analytic content, articles focused solely on urban design or descriptive studies of household satisfaction. The 75 articles retained for the review were published in 44 different journals. The list of journals and the article count for each are presented in Table 2. Topically, the journals can be grouped into four broad research areas: Housing, Transportation, Methods (spatial, geographic, cartographic), and Other. By percent, urban studies journals published just over one-third of the articles, followed by housing journals (26% of articles), and transportation journals (22%).

Citations for the articles in the review range from 0 to 92, with a mean of 6.3 (see Figure 1). The most frequently cited article is Forsyth, Oakes, Schmitz and Hearst's 2007 study of 715 residents of the Twin Cities (Minnesota, USA), analyzing the relationship between urban form characteristics and physical activity. Other highly cited papers include Frenkel and Ashkenazi (2008, 57 citations), and Jiang, Liu, Yuan, and Zhang (2007; 26 citations).

Figure 1: Articles by Number of Citations (N=75)

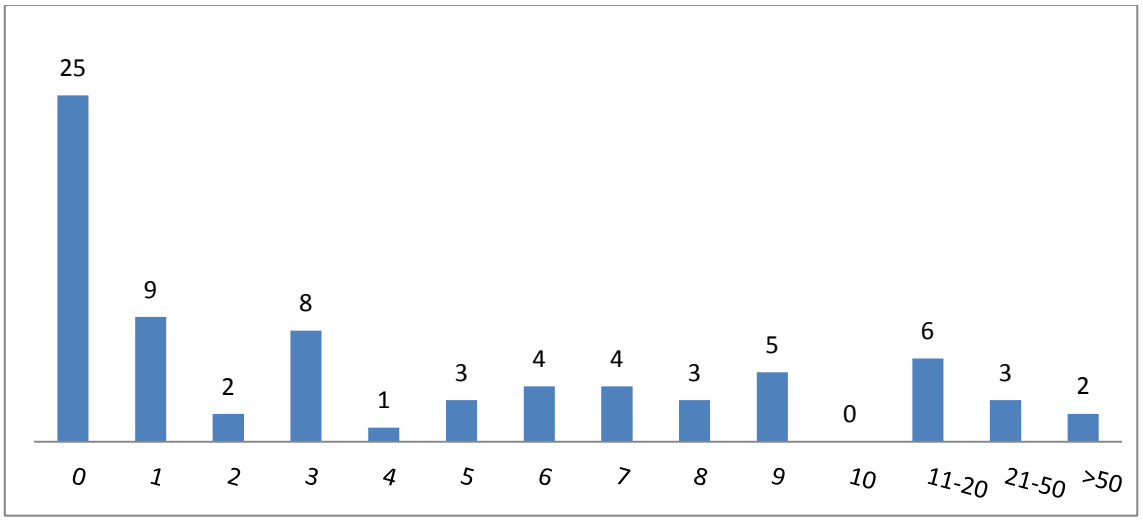
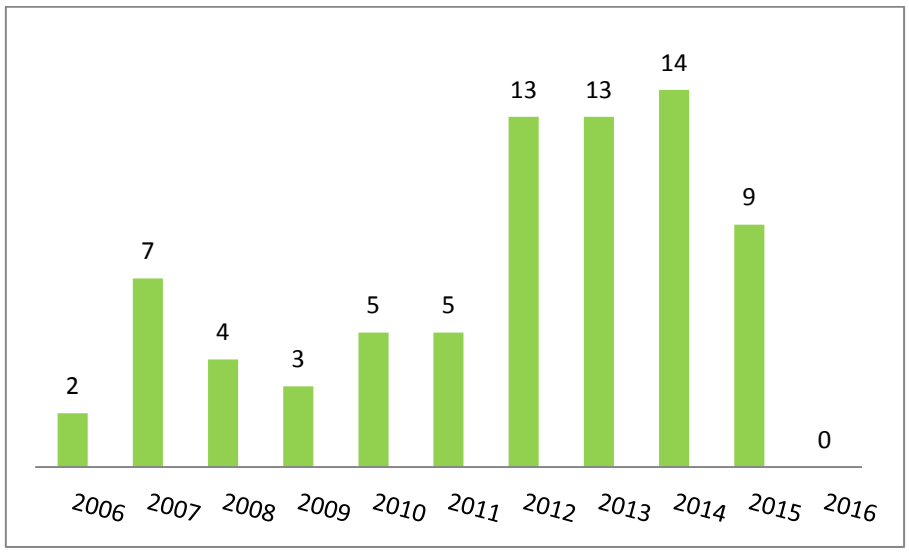


Figure 2: Number of Articles by Publication Year (N = 75)



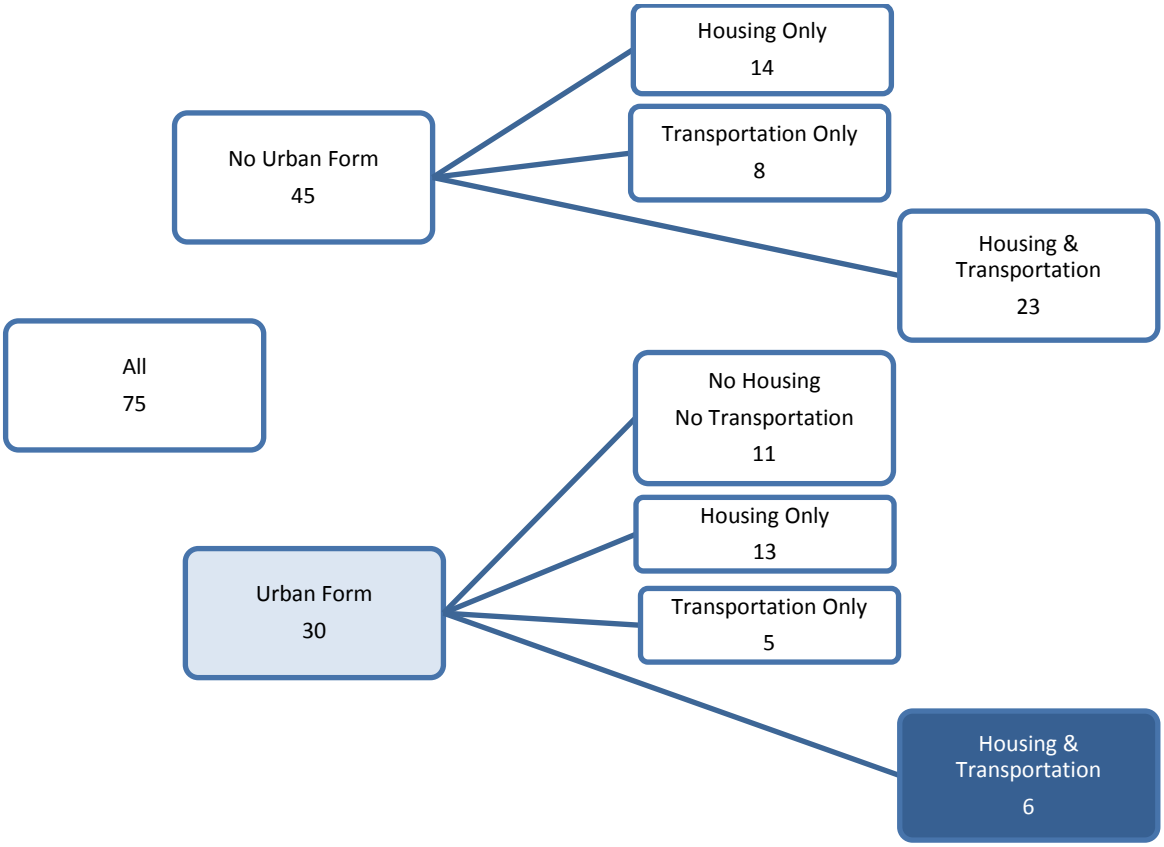
By publication year, there was a marked increase in the number of articles published in 2012, from 5 in 2011 to 13 (see Figure 2). The higher rate of publication continued in 2013 and 2014, with a drop in 2015 to 9 articles, although this may be attributable to incomplete indexing of articles in the SSCI database. (The time lag between publication and indexing also explains the lack of articles published in 2016.) The pattern suggests there has been a recent uptick in scholarly interest in the interrelationship between urban form, housing affordability, and transportation affordability.

Table 2: Journals Represented in the Review, by Topical Area

Journal	Articles	Journal	Articles
Urban Studies (39%)		**Housing (25%)**	
CITIES	3	HOUSING POLICY DEBATE	8
ENVIRONMENT AND PLANNING B-PLANNING & DESIGN	2	HOUSING STUDIES	4
J. OF URBAN AFFAIRS	2	HABITAT INTERNATIONAL	3
J. OF URBAN PLANNING AND DEVELOPMENT	2	OPEN HOUSE INTERNATIONAL	2
REGIONAL SCIENCE AND URBAN ECONOMICS	2	HOUSING THEORY & SOCIETY	1
URBAN GEOGRAPHY	2	J. OF HOUSING AND THE BUILT ENVIRONMENT	1
URBAN STUDIES	2		
DEVELOPMENT SOUTHERN AFRICA	1	**Transportation (23%)**	
ENVIRONMENT AND PLANNING A	1	TRANSPORTATION RESEARCH RECORD	5
EUROPEAN PLANNING STUDIES	1	TRANSPORT POLICY	4
EVALUATION AND PROGRAM PLANNING	1	J. OF TRANSPORT GEOGRAPHY	3
INTERNATIONAL J. OF URBAN AND REGIONAL RESEARCH	1	TRANSPORTATION RESEARCH PART A-POLICY AND PRACTICE	2
J. OF THE AMERICAN PLANNING ASSOCIATION	1	ROAD & TRANSPORT RESEARCH	1
J. OF PLANNING EDUCATION AND RESEARCH	1	TRANSPORT REVIEWS	1
J. OF URBAN ECONOMICS	1	TRANSPORTATION RESEARCH PART D-TRANSPORT AND ENVIRONMENT	1
J. OF URBAN PLANNING AND DEVELOPMENT	1	1	
LAND USE POLICY	1		
LANDSCAPE AND URBAN PLANNING	1		
PROGRESS IN PLANNING	1		
REGIONAL STUDIES	1		
URBAN FORESTRY & URBAN GREENING	1		
Methods (5%)		**Other (8%)**	
COMPUTERS ENVIRONMENT AND URBAN SYSTEMS	1	AMERICAN J. OF HEALTH PROMOTION	1
GEOCARTO INTERNATIONAL	1	INTERNATIONAL J. OF PHYSICAL SCIENCES	1
J. OF GEOGRAPHICAL SCIENCES	1	REAL ESTATE ECONOMICS	1
J. OF MAPS	1	SCOTTISH J. OF POLITICAL ECONOMY	1
		SOCIAL INDICATORS RESEARCH	1
		SUSTAINABILITY	1
		TECHNOLOGICAL FORECASTING AND SOCIAL CHANGE	1

The 75 retained papers were then coded to indicate if an article explicitly addresses urban form, housing affordability, transportation affordability, or some combination of these concepts. Figure 3 displays the distribution of papers by concept.

Figure 3: Articles by Concept Categories



Only 8% of retained articles included all three concepts in an integrated way (dark blue box in Figure 3). These articles are quite diverse, representing a range of journals, disciplines, methods, and intended audiences for the work; urban form is incorporated into the analyses as an outcome or result, as a predictor (independent variable), or as an associated characteristic. These 6 articles are listed below, along with a brief comment on the general thrust of the study and how each operationalized and applied measures of urban form (see also Appendix 1 for greater detail):

- Fisher, LM; Pollakowski, HO; Zabel, J. 2009. Amenity-Based Housing Affordability Indexes. REAL ESTATE ECONOMICS, Vol 37, Issue 4, pp 705-746.
    - Metrics of population density, % open space in a jurisdiction, and a time-based job accessibility index are used to calculate adjustments to town-level housing affordability rankings in the Greater Boston Region; general perspective is understanding and improving social equity through affordable housing planning and policy.
- Talen, E. 2010. Affordability in New Urbanist Development: Principle, Practice, and Strategy. JOURNAL OF URBAN AFFAIRS, Vol 32, Issue 4, pp 489-510.
    - Qualitative study of the limits to creating affordable housing through New Urbanist design which creates increased density and higher levels of walkability and mixed use; high land costs and the demand for high-amenity neighborhoods erode the

ability of these developments to deliver affordable housing; general perspective is to expand the New Urbanist emphasis on design to address planning practice and policy for developer incentives or regulatory mandates for affordable dwelling units.

- Rowe, DH; Bae, CHC; Shen, Q. 2011. Evaluating the Impact of Transit Service on Parking Demand and Requirements. TRANSPORTATION RESEARCH RECORD, Issue 2245, pp 56-62.
    - Empirical study of parking demand in two sub-regions of Seattle, Washington; urban form metrics include density, block size, land uses, and a transit 'level of service' index with metrics for frequency of service, daily time span of service, on-time performance, and the time differential between transit and driving; overall perspective is to reduce minimum parking requirements in transit-rich locations so as to reduce the overall costs of development, in turn increasing the supply of affordable housing.
- Larson, W.; Liu, F.; Yezer, A. 2012. Energy footprint of the city: Effects of urban land use and transportation policies. JOURNAL OF URBAN ECONOMICS, Vol 72, Issues 2-3, pp 147-159.
    - Simulation model using scenarios of changes to vehicle fuel prices, vehicle fuel economy, and land development policies to model effects on housing density, housing type, and city size; overall perspective is to test impacts of various policy options on energy consumption as a sustainability-related outcome.
- Patterson, Z; Saddier, S; Rezaei, A; Manaugh, K. 2014. Use of the Urban Core Index to analyze residential mobility: the case of seniors in Canadian metropolitan regions. JOURNAL OF TRANSPORT GEOGRAPHY, Vol 41, pp 116-125.
    - Study of location choices over time by senior residents in 6 Canadian cities; revise an administrative definition of 'urban core' which uses the share of housing built prior to 1946, to add the share of housing that is non-single family detached dwelling units and the percent of trips made by transit; overall perspective is to evaluate demographic shifts in cities although these scholars find no evidence for the claim that seniors are moving to urban core zones.
- Winston, N. 2014. Sustainable Communities? A Comparative Perspective on Urban Housing in the European Union. EUROPEAN PLANNING STUDIES, Vol 22, Issue 7, pp 1384-1406.
    - Cross-country comparison of the sustainability of urban neighborhoods in EU countries; urban form represented by a measure of mixed use, plus European Quality of Life Survey (EQLS) responses on walkable access to routine household needs (e.g. bank, grocery, post office) and a rating of the quality and accessibility of transit; overall perspective is to rank EU countries by progress towards sustainability, including sustainable housing which considers housing as part of a broader community system.

The very small number of studies, along with the diversity of research questions makes it difficult to identify patterns in methods of measuring urban form in connection with affordable of housing and transportation. This diversity can be understood as a reflection of the complexity of these inter-related concepts, and of the variety of disciplines represented, from urban design, to sustainability science, planning, housing policy, regional science, and urban demographics. The diversity confirms the interdisciplinary nature of location affordability, both as a topic of study itself and as a relevant component in research of other topics.

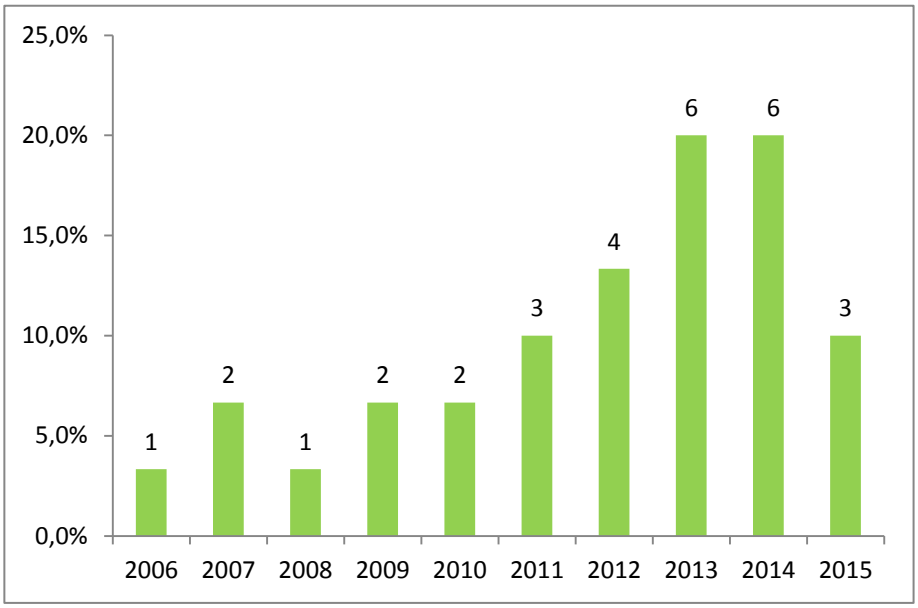
Articles Measuring Urban Form

To broaden the content of this review, the following section takes a more detailed look at the 30 articles that addressed urban form (light blue box in Figure 3), with or without also including housing or transportation in the analysis. The articles included in this detailed review are provided in Appendix 1. Here, the articles are coded for characteristics of the measures of urban form, how urban form functions in the analysis, along with some characteristics of the article and the first author:

- Scale of urban form measure
    - Region or Sub-region
- Single or multiple metrics of urban form
- Type(s) of measure(s)
    - Cartographic (physical structures; example: density of housing)
    - Demographic (socio-economic information; example: density of population)
    - Mixed (cartographic and demographic)
    - Not defined
- Function of urban form measures in the analysis
    - Predictor or independent variable
    - Outcome, output, or dependent variable
    - Associated characteristic (descriptive studies)
- General topical interest of the article
    - Urban growth and/or change
    - Social outcomes
    - Sustainability
- Target audience for research
    - Regional science
    - Planning practice
    - Equity
    - Housing policy or planning
    - General policy making
    - Urban design
    - Public health
    - Transportation planning
- Discipline of first author
    - Regional science
    - Planning
    - Economics
    - Architecture/Landscape architecture
    - Other

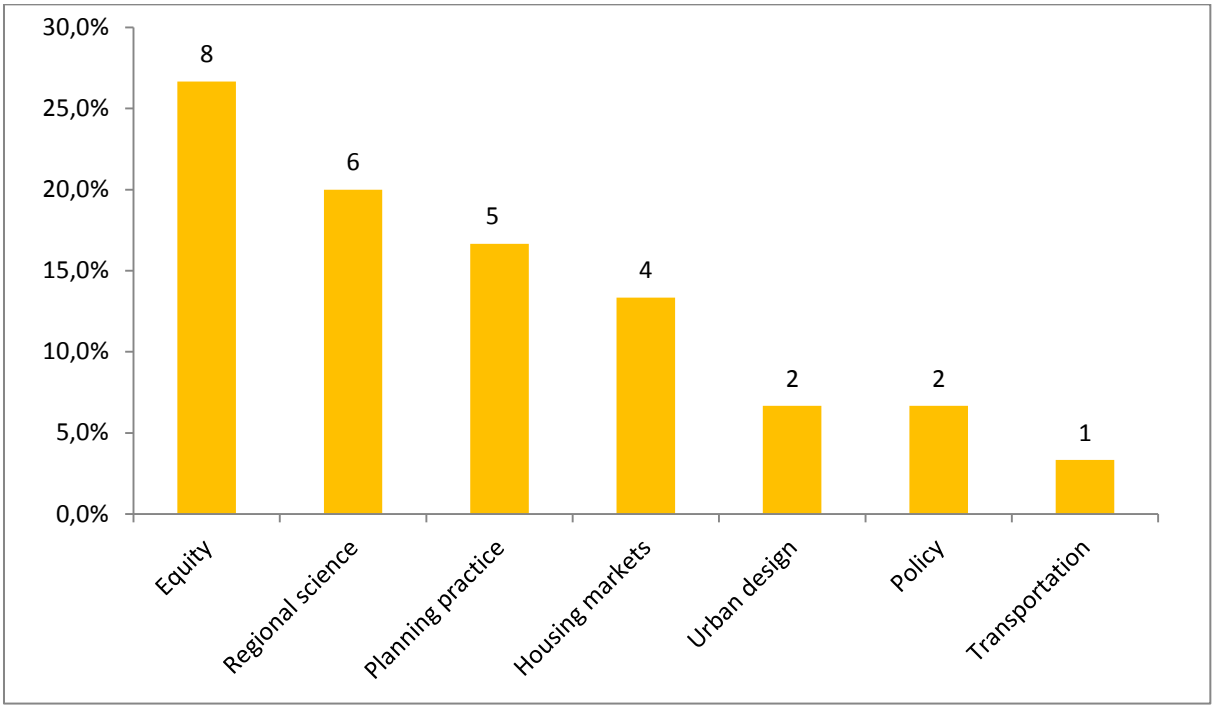
As for the larger set of 75 articles, the 30 articles that include a measure urban form show a general pattern of more articles per year over time (again, that the decline from 2014 to 2015 may represent incomplete cataloguing of articles in the database; see Figure 4).

Figure 4: Share and Number of Articles by Year of Publication (N = 30)



The largest group by target audience includes the articles that orient their conclusions and implications of results toward some dimension of equity, without addressing a particular community or practice or specific subdiscipline. Twenty percent of articles were aligned toward regional science, followed by planning practice at 17%. Relatedly, nearly half of the first authors are in the discipline of planning, followed by regional science at just over 25%, and minor shares in other disciplines (see Figure 5).

Figure 5: Share of Articles by Target Audience (N=30)



Metrics and Measures

Turning to the basic characteristics of the measures used, Table 3 presents the number and share of articles using various approaches to measuring urban form. The articles are quite evenly split on whether urban form is measured at the regional scale or the sub-regional scale, as well as whether urban form is measured by cartographic, demographic, or some combination of these types of characteristics. Two-thirds of articles use multiple metrics of urban form. In terms of methodological function, 14 articles (46%) use urban form as an outcome, dependent variable, or output of a simulation model, while about one-third employ measures of urban form as predictors of some other outcome of interest, and one-third as characteristics associated with the main variable of interest (the latter chiefly descriptive studies or cross-case comparisons that do not make causal links with urban form).

Table 3: Share of Articles, by Characteristic of Urban Form Measure (N = 30)

Characteristic	Num.	Percent
Scale of Measure		
Region	15	50.0
Sub-region	14	46.7
Unknown or NA	1	3.3
Type of Measure		
Cartographic	10	33.0
Demographic	8	26.7
Mixed	9	30.0
Unknown	3	10.0
Number of Dimensions		
Monodimensional	10	33.3
Multidimensional	19	63.3
Unknown or NA	1	3.3
Methodological Function for Urban Form		
Predictor or independent variable	7	23.3
Outcome, output, or dependent variable	14	46.7
Associated characteristic	9	30.0

There is some variation in the characteristics by target audience. Among the 6 articles targeted to the regional science discipline, all the analyses use urban form as an outcome or dependent variable. In this group, half of the articles use measures that mix cartographic and demographic metrics and much more commonly measure urban form using multiple metrics (4 articles) and at the regional scale (5 articles). Although the numbers are small, the distribution fits with the traditional interests in the regional science discipline: the region itself as object of study, and an interest in connections between built systems (cartographic) and socioeconomic (demographic) factors.

The 5 papers oriented toward the practice of planning were more likely to measure urban form at the sub-regional level (4 papers and 80%). Among these articles, the methodological function of urban form is split, with 2 using urban form as an associated characteristic and 3 using urban form as

an outcome. This suggests an alignment with the local or neighborhood scale of much of planning work, as well as conceptualizing urban form as both a means to achieve objectives as well as a objective in itself.

Among the 8 equity articles, however, urban form is far less often an outcome of interest (1 article); 3 articles use urban form as a predictor variable and 4 as an associated characteristic. More equity articles used a monodimensional measure of urban form (4 or 50%) than any other group, reflecting the conceptualization of urban form as a control or contextual element and a research orientation toward socio-economic phenomena. This substantive interest is also supported by the type of measures used, with more demographic (3 articles or 37.5%) and mixed measures (3 or 37.5%) than cartographic measures (1; 12.5%; 1 equity article included an undefined typology). Just over half of these articles used a sub-regional scale.

To gain further insights into recent methods for measuring urban form, the measures used in the articles are also coded as to their substantive content:

- Density (example: population density or housing unit density)
- Spatial configuration (example: degree of clustering or scatter of single family dwelling units)
- Urban extent (example: geographic size of city)
- Joint configuration (example: proximity of housing to jobs or share of households within ½ mile of a transit station)
- Transportation (example: transit frequency or street network characteristics)
- Typology or categorical variables (example: rural, urban, suburban)
- Descriptive methods (examples: good environment or unquantified variables of diversity)

Density is a widely accepted measure of urban form, and indeed it is used more frequently than any other type of metric (16 articles or 53%). Spatial configuration metrics are the next most common, appearing in 13 (43%) of articles. That these traditional metrics appear in just half of the papers in this review again reflects the diversity of disciplines and research questions represented in the sample. The third most common metrics are those of joint configuration, which are used in 10 articles (33%). Other types of metrics each appear in 5 or fewer papers.

As described previously, most articles use multidimensional measures of urban form, although those using a single metric most often use either a density metric (4 articles or 13% of all articles) or a spatial configuration metric (4 or 13%). Articles using multiple dimensions usually use metrics of more than one type, although one article uses multiple metrics of density and another uses multiple metrics of joint configuration. Multiple categorical variables or descriptive characteristics were used in 4 articles. The most common structure of a multidimensional approach combines density metrics and spatial configuration metrics (8 articles or 27% of all articles), with combinations of density and joint configuration metrics almost as frequent (7 or 23%). Combinations of joint configuration and spatial configuration metrics are nearly as common, appearing in 6 articles (20%).

Summary and Discussion

Overall this review supports the view that multidimensional approaches to measuring urban form are favored over using a single metric, and scholars usually combine different types of metrics. The diversity of metrics used may reflect the increasing amount of data available, especially spatial data,

as well as the complexity of urban systems themselves. Increased computing and processing capacity that enable the use of more complex and larger datasets may also expand the list of available methods. The overall increase in data availability and computing power may be fueling an increase in the number of articles that include urban form. Alternatively there may be a general increase in scholarly interest in the effects of urban form, leading researchers in disciplines that have not traditionally included urban factors in their analyses to begin to use them.

Several articles in this review are directly concerned with expanding existing approaches to measuring urban form. Hamidi et al (2015) present a multi-dimensional index or urban sprawl that builds on previous work, updating a 2000 sprawl index by adding new metrics and updating older datasets to measure 2010 conditions. To construct the index, these researchers collected an extensive list of metrics from the literature, which they reduced using a principle component analysis to identify four factors: development density, land use mix, activity centering, and street connectivity, the latter a completely new dimension. The 2010 Sprawl Index includes values for 221 U.S. metropolitan areas and is made freely available at https://gis.cancer.gov/tools/urban-sprawl/. Somewhat similarly, Patterson et al (2014) expand on an existing administrative method for defining the urban core of Canadian cities by adding housing and transportation metrics, factors hypothesized to be important for their population of interest, as a methodological adjustment to more closely align with a specific policy question.

These multi-dimensional approaches are favored among the scholars represented in this review. Such approaches can offer important detail, as noted by Sarzynski et al. (2014) who conclude that the more nuanced results that a multidimensional approach provides can identify 'the particular land use dimension that is seen as causing the most detrimental outcomes'. Such information can be important for informing policies that take into account the 'disparate impacts depending on region, metropolitan scale, type, and location" (p. 40).

At the same time, the wide array of metrics used, even in the small sample of papers included in this review, reveals a challenge for scholars as well as those who draw from the literature to inform policy and practice. While this diversity may be a sign of innovation in scholarly research, it also poses a challenge for the policy and practice communities who, ideally, use research results to inform their work. The lack of consistently used definitions of urban form is likely a factor in the mixed results across studies, which produces unclear signals for those charged with determining an effective course of action to achieve a particular socio-economic goal. An example of this problem is demonstrated by one of the articles included in this review from the discipline of public health. In their study of the effect of density on physical activity, Forsyth et al. (2007) explore the complexity of a single dimension of urban form: density. They use several definitions of density, including population density, housing density, employment density and lot coverage, and at different scales. These scholars acknowledge the complexity of using a single metric of density to capture the factors that shape human behavior and find weak and somewhat inconsistent relationships, depending on the metric chosen.

The short time period covered in this review and the use of a single database limits the number of articles included in study. These limitations also preclude a formal meta-analysis of the magnitude and direction of effects. However, the review allows for some observations about the recent literature:

- Urban form is more commonly measured with a multidimensional approach than with a single metric.
- While density is a common metric, it is usually combined with other metrics, usually the configuration of a single phenomenon or of the joint configuration of two interrelated phenomena.
- Studies that target their results and implications of their findings toward issues of equity in housing and/or transportation are including measures of urban form in their analyses.
- Studies in regional science emphasize urban form as an outcome of interest, while studies that seek to inform planning practice or questions of equity may include urban form as a predictor variable or an associated characteristic.
- The number of published studies that link urban form and affordability of housing and/or transportation is increasing.

The complexity of urban form and the interrelationships between housing and transportation suggest there remains much work to do in understanding LA. An evidence base for effective affordability policy will be grounded in an understanding of the links between housing, transportation, and characteristics of urban form. Contributions to this evidence base from the research community will, by definition, involve cross-sectoral research questions. Sifting the literature for new and emerging approaches to measuring urban form can offer important inputs for LA research, especially in connection with identifying approaches that employ new data resources and methods. The results also suggest that developing appropriate, rigorous, yet workable methods for understanding the effects of urban form in LA will require interdisciplinary work that weaves together methods and concepts from a scattered literature landscape to develop a coherent and actionable research and policy agenda.

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The Center for Neighborhood Technology and the Center for Transit-Oriented Development. 2006. The Affordability Index: A New Tool for Measuring the True Affordability of a Housing Choice. Brief for The Brookings Institution, Washington, D.C. Available at: http://www.brookings.edu/research/reports/2006/01/01-affordability-index.

Sarzynski, A., G. Galster, and L. Stack. 2014. Evolving United States metropolitan land use patterns. *Urban Geography*, 35:1, 25-47.

Appendix 1: Summary of 6 Articles Linking Urban Form, Transportation, and Housing

Author, Year	Research Question	UF Measurement Method	Substantive content	Function of UF measure in study	Caveats	Effect on Transp.	Effect on Housing
Fisher et al. 2009	How is the distribution of affordable units in greater Boston affected when location amenities are accounted for?	Variables included in hedonic model	• Population density • % open space in town • Time-based index of employment accessibility	Control variables in hedonic model Accessibility index used as a factor to adjust housing cost	• Conceptually conflicting in using hedonic model and assuming location factors capitalized into housing markets but then adjusting housing prices to account for those same measures. • Weak measures. • Accessibility index based on time, not pecuniary cost, does not account for mode differences.	NA	Accounting for accessibility, crime, and school quality alters the rankings of towns by affordability
Talen 2010	How is the market behaving in providing affordable housing in NU developments? Can market-based NU developments include affordable price levels? What kinds of places are NU developments most likely to have a mix of prices/ housing types?	Implicit in the study of New Urbanist developments	• Denser because lot sizes are smaller and DUs are smaller • Walkable neighborhoods • Mixed use	Defines sample frame Classification scheme for broader locational context of each development included, but not elaborated (urban infill, sprawl, rural area, developed suburb)	• Developments included in study are those somehow listed as New Urbanist by the Congress for New Urbanism	NA	Design-only approach to creating income-based social diversity—the dominant approach in NU—is possible, but rare when not supported by low land costs and/or regulatory intervention.

Author, Year	Research Question	UF Measurement Method	Substantive content	Function of UF measure in study	Caveats	Effect on Transp.	Effect on Housing

Rowe et al 2011	Do accepted guidelines for parking supply in residential developments result in an oversupply of parking that increases cost of housing?	List of characteristics of development areas	• Population/square mile
			• Employment/acre
			• DUs/ acre
			• Average parcel size
			• % land use: commercial, residential, parks, other
			• Average block size
			• Intersection density
			• Transit LOS:
			  • % residents within ¼ mi of high frequency service
			  • span of service (hours)
			  • travel time differential to major employment centers compared to driving
			  • % on time operations
				Descriptive of conditions for two case study sites	• Limited sample of 8 residential developments
					• Current transit LOS may not reflect conditions at time of development
					• Aggregation issues with transit LOS measure (calculated at area level, parking demand at site level)
						Hypothesize lower driving and car ownership in transit-rich locations	Hypothesize higher development costs when parking is oversupplied. Zoning and design guidelines contain a suburban bias.

Patterson et al 2014	Are seniors moving to urban core in Canadian cities?	Index (unweighted sum of z-scores)	• % DUs built before 1946 • % non-single family detached DUs • % trips by transit or active mode	Definitional	• Defined using 1996 conditions • No spatial effects • Weak mobility measure	NA	NA
Winston 2014	Which EU countries have the highest levels of urban housing sustainabilty?	Composite index of neighborhood characteristics	• Mixed use index of percentage of EQLS respondents reporting walkable access to services • % of national housing stock that is multi-family	Descriptive of conditions for cross-country comparison	• Combines data from urban areas with national level variables	Not linked	Not linked

Author, Year	Research Question	UF Measurement Method	Substantive content	Function of UF measure in study	Caveats	Effect on Transp.	Effect on Housing
Larson et al. 2012	How do changes in development policy and transportation policy affect land use patterns and energy consumption? What policy changes disproportionately affect lower income households' utility?	Average values from 5 cities (ACS and AHS data)	• Lot size for detached DUs • DU size in square feet • FAR at edge of CBD • Area of city in square miles • % housed in 1, 2-4, 5+ unit structures	Calibration and outputs for an urban simulation model	• Substantial measurement error in data for calibration • Assume all workers commute to a single CBD • Assumes all households have the same cost for a 'unit' of commuting • Based on neoclassical utility models	Greenbelt policy reduces commuting time; 5% open space requirement increases commuting time; density caps increase commute time; suburban large lot zoning reduce total commute time by densifying inner areas.	Rebound and indirect effects on land markets from changes to commuting costs. Increasing cost of driving reduces DU size, increases housing price; increasing fuel efficiency increases commuting and expands urban area thus lowering housing prices. Greenbelt policy only scenario better for low-income HHs than for high income HHs because reduces their utility less.

Appendix 2: 30 Articles with Measures of Urban Form

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Kew, B; Lee, BD. 2013. Measuring Sprawl across the Urban Rural Continuum Using an Amalgamated Sprawl Index. SUSTAINABILITY, Vol 5, Issue 5, pp 1806-1828. Doi: 10.3390/su5051806 Citations: 3

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