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Global comparative analysis of urban form — using spatial metrics and remote sensing

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Abstract

Currently, debates over urban form have generally focused on the contrast between the "sprawl" often seen as typical of the United States and "compact" urban forms found in parts of Europe. Although these debates are presumed to have implications for developing worlds as well, systematic comparison of urban forms between developed and developing countries has been lacking. This paper utilized satellite images of 77 metropolitan areas in Asia, US, Europe, Latin America and Australia to calculate seven spatial metrics that capture five distinct dimensions of urban form. Comparison of the spatial metrics was firstly made between developed and developing countries, and then among world regions. A cluster analysis classifies the cities into groups in terms of these spatial metrics. The paper also explored the origins of differences in urban form through comparison with socio-economic developmental indicators and historical trajectories in urban development. The result clearly demonstrates that urban agglomerations of developing world are more compact and dense than their counterparts in either Europe or North America. Moreover, there are also striking differences in urban form across regions.

Keywords: Land use; ETM; Cluster analysis; Urban form; Developing countries

1. Introduction

With the increasing acceptance of sustainable development as a guiding concept, researchers have focused renewed attention on matters of urban form that trace back to the start of the modern planning and urban studies (Howard, 1898; Burgess, 1925; Hoyt, 1939; Harris and Ullman, 1945; Conzen, 2001). A growing body of literature looks to a "good city form" or "sustainable urban form" to enhance economic vitality and social equity, and reduce the deterioration of the environment (Breheny, 1992; De Roo and Miller, 2000). Recent discussions of "urban sprawl" in the United States and the "compact city" in Europe manifest this growing preoccupation (Ewing, 1997; Brueckner, 2000; Johnson, 2001). In the United States, both the Smart Growth movement (Gillham and Maclean, 2001; Lincoln Institute of Land Policy, 2001) and the New Urbanism movement (Duany et al., 2000; Leccese and McCormick, 2000) have advocated policies similar to those of the compact city movement in Europe. Although the debate over whether a "sprawling" urban form is best for the quality of city life has not been fully settled (Soja, 2000; Dear, 2001; Richardson and Gordon, 2001), most authors oppose North American models of "sprawl" to the more compact forms of many European urban regions (Nivola, 1999; Beatley, 2000; Dieleman and Wegener, 2004).

Despite the growing vigor of debates on these issues, rigorous and comprehensive exploration of actual cross-national differences in urban form has remained surprisingly scarce. Only recently have quantitative methods emerged as a means to more systematic classification and analysis of the issues in these debates (Torrens and Marina, 2000; Wassmer, 2000; Galster et al., 2001; Ewing et al., 2002; Tsai, 2005). Thus far, applications of these methods have remained confined to individual case studies or specific national contexts, usually within developed countries. Torrens and Marina (2000) distinguished varieties

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of urban form by indicators for density, scatter, leapfrogging, interspersion, and accessibility. Wassmer (2000) tried to introduce consensual methods to measure and compare urban sprawl in the metropolitan area. Galster et al. (2001) captured eight dimensions of sprawl: density, continuity, concentration, clustering, centrality, nuclearity, mixed uses, and proximity. Ewing et al. (2002) created a sprawl index based on four factors (i.e. residential density, neighborhood mix, activity strength and accessibility) for US cities. Tsai (2005) employed four quantitative variables (i.e. metropolitan size, activity intensity, distribution degree and clustering extent) to differentiate compactness from sprawl. Others (Longley and Mesev, 2000; Filion and Hammond, 2003; Song and Knaap, 2004) employed multi-dimensional indicators to measure compactness within specific neighborhoods or cities.

As the overwhelming proportion of urban growth in the next century will take place in developing countries (United Nations (UN), 1996), the question of urban form in these more dynamic settings has especially pressing relevance for policy. Yet not only debates about urban form, but quantitative work on indicators rarely focuses on metropolitan regions there. Even in more developed Asian mega cities like Seoul and Tokyo, indiscriminate application of measures from Europe and North America have proved inappropriate (Jenks and Burgess, 2000; Yokohari et al., 2000). Prescriptions derived from contemporary planning movements in Europe or North America (e.g. Compact city, Smart Growth, New Urbanism) may be even less applicable to the cities of developing countries. Research on the most polluted mega cities of the developing world has already pointed to the very compact nature and high density of cities in China, India and Mexico (World Health Organization (WHO), 1998 in Wang, 1999).

To address these pressing issues requires a global comparative perspective on urban form and its evolution. A more systematic understanding of the global variants in urban form and their sources is a crucial prerequisite to such a perspective. Satellite images offer an unprecedented opportunity to develop the more precise comparative indicators that are necessary. In employing these data for the first time in a global comparative analysis of systematic indicators, this article investigated whether urban agglomerations of the developing world are more compact and dense than their counterparts in either Europe or North America. Cluster analysis further explored the broad regional differences. Reasons for these contrasts were examined by using socio-economic indicators. Comparative analysis of differences in trajectories of institutional, economic and urban development, combined with additional visual evidence from the satellite images was conducted to examine how the contrasts within and between world regions have emerged.

2. Methodology

2.1. Data processing

Although urban area can be delineated from the traditional sources such as topographic maps, administrative maps, and even tourist maps, there is no universal and consistent way to represent the urban area among various countries using these maps. Thus, remote sensing images that record real ground objects at a given time will be used in this research. Satellite images of 77 urban regions worldwide came from the Global Land Cover Facility, a website which offers comprehensive, free satellite images of places worldwide for land use/cover research. The selected cities included most of the largest urban regions in the United States, Australia (and New Zealand), Europe, Asia and Latin America (LA) (Appendix A). Although this sample encompassed as many cities as possible, the selection fell short of complete coverage in several respects. First, most cities in the tropical area and mountain area are often heavily covered by cloud, which excluded all South-East Asian cities and some mountainous cities in South America. Second, for many cities in US and West Europe, it was difficult to distinguish the urban area precisely from the surrounding metropolitan region. This led to the exclusion of cities like Los Angeles, New York in US and Liverpool in UK. Third, available images of African cities were too scarce to constitute a comparable regional dataset. The sample therefore included no African cities. When the database contained multiple images of a selected city, preference was given to ones showing the better quality for visual interpretation. To make the data consistent, all but one of the images selected were ETM imagery of 1999, 2000 or 2001 with a higher spatial resolution of 14.25 m in its panchromatic band. (The image of Bogota, the only exception, had a spatial resolution of 28.5 m.) Since most images were taken in the summer season, similar spectrum characteristics for the land cover were generally assured.

There are various ways to define what is “urban” and what is part of an “urban area” in different countries (Carter, 1981). In Britain, open space that is completely surrounded by the other urban land use types (e.g. residual, industrial, and commercial, etc.) belongs to an “urban area” (Carter, 1981). In China, collective-owned nursery land may be defined as farmland even when it is completely surrounded by urban land use types (Li, 1991). Similarly, it is often a subjective matter to decide whether a lake or coastal waters within or beside an urban area should be allocated to the “urban” or not. To resolve this problem the definition applied in this research confined the urban area to the built up or urbanized area as indicated in the images. Green fields and water bodies not directly related to human development activities were not classified as part of this “urban area”.

As each scene of satellite image covers a huge area, the urban region was firstly clipped on the basis of visual observation with the assistance of the available metropolitan boundaries (e.g. US cities). Images which combined 4, 3, 2 bands in RGB made it easy to differentiate the urban area from the non-urban area, as the urban area appeared bluish-grey to steel-grey (Gupta and Prakash, 1998). Exclusion of the non-urban land use types, most of which are vegetation and water body, also facilitated image classification. After image enhancement with the higher spatial resolution in panchromatic band, four principal easily interpreted urban land use types, i.e. residential settlement, road, industrial and warehouses, were selected for this procedure (Gupta and Prakash, 1998). The most commonly used supervised classification method, Maximum Likelihood, was executed with the designated likelihood of 95% for each urban

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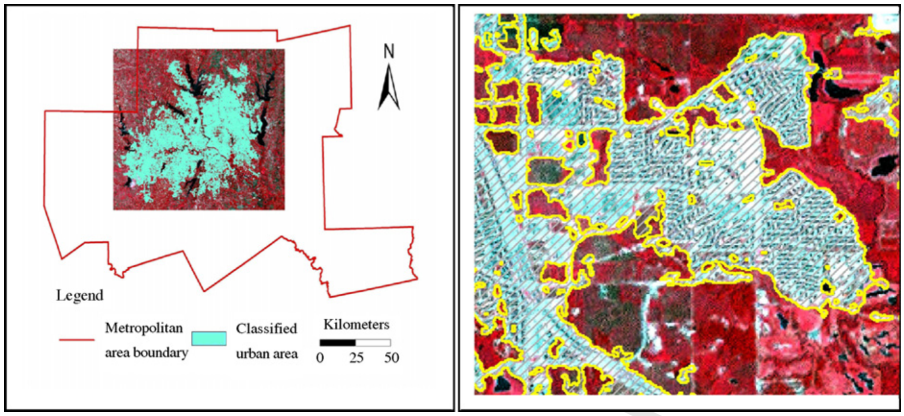

Fig. 1. One example of the classified urban area in Dallas, TX, USA. The left panel represents the extracted urban area superimposed over the metropolitan boundary. The right panel is a magnified view of the classified urban area. Scale of the right view is 1:23,000.

land use type. Finally, the four urban types were merged to constitute the "urbanized area". A median filter was used to remove noises or speckles in the imagery prior to classification. After classification, majority analysis was carried out to dissolve the spurious pixels within a large single class. All Image processing works were implemented in ENVI 3.5, a professional remote sensing platform of RSI (Research Systems Inc.).

Classified images were then transformed into "shape" vector format, and introduced into ArcGIS 8.3, a GIS package of ESRI (Environmental Systems Research Institute, Inc). The clipped urban image was superimposed as the background for correcting the misclassified part in the image processing. To facilitate the future computation of spatial metrics, small and isolated patches (e.g. smaller than 1 ha) in the relatively outlying area were removed. Cross-checks were undertaken to ensure that the urbanized areas remained within the available metropolitan boundaries (see one example of Fig. 1).

The analysis of the spatial metrics thus extracted employed multiple methods. In addition to comparisons between developed and developing countries in terms of the UN's country development classificatory codes (UN, 2005), and between different world regions (i.e. U.S., Europe (EU), Asia, Latin America (LA) and Australia/New Zealand (AU), the analysis took the further step of examining patterns among the spatial metrics themselves. Cluster analysis in SPSS 12.0, a widely used statistics package, was used to extract characteristic patterns in urban form for assessment of their incidence by region. The cluster analysis employed a combination of hierarchical and K-Means cluster methods to maximize the power of the results. First, hierarchical cluster analysis was used to obtain the rough number of classifications; then K-Means cluster analysis, which utilized the number of groups extracted from the hierarchical analysis, was executed to make the classification. The K-Means method had the advantage that it enabled the group centers to be adjusted iteratively.

Analysis of the sources of variation in urban form drew on additional methods. A cross-sectional analysis of the socio-economic correlates of urban form employed acknowledged indicators for national wealth (Gross Domestic Product (GDP) per capita ((Purchasing Power Parity) PPP US$) (United Nations Development Programme (UNDP), 2001)), transportation and telecommunication (national main telephone lines/1000 people (TELP) and national vehicles/1000 population (VEHPOP) (World Bank, 2000)). Finally, the comparison among trajectories of urban development synthesized secondary literatures on the history of urban, political and economic development in various world regions with additional visual evidence from the satellite images.

2.2. *Definition of spatial metrics*

The spatial metrics employed here are a series of quantitative indices representing physical characteristics of the landscape mosaic. The seven metrics represent five dimensions of the urban form, i.e. compactness, centrality, complexity, porosity and density (Table 1).

2.2.1. *Complexity (Fig. 2a)*

This index measures the irregularity of the patch shape. Two complexity metrics employed are the area weighted mean shape index (AWMSI) and the area weighted mean patch fractal dimension (AWMPFD) (definition see McGarigal and Marks, 1995). The former mainly represents the shape irregularity of the patches. The higher this value is, the more irregular the shapes are. The latter metric mainly describes the raggedness of the urban boundary. It derives from the fractal dimension, a measure that is very "suited to summarizing the jaggedly irregular land use patterns that characterize real world cities" (Longley and Mesev, 2000). This fractal dimension approaches one for shapes with simple perimeters and approaches two when shapes are more complex.

2.2.2. *Centrality (Fig. 2b)*

In the study by Galster et al. (2001), centrality was the degree to which the urban development is close to the central business district (CBD). Similarly, the centrality index in this research measures the average distance of the dispersed parts to the city centre, which was defined as the centroid of the largest patch. To minimize the bias of the urban scale, the average distance was divided by the radius of a circle with the total urban area. There-

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Table 1
Spatial metrics and socio-economic indicators (McGarigal and Marks, 1995; World Bank, 2000; UNDP, 2001)

Indicators	Abbreviation	Formula	Description
Area weighted mean shape index	AWMSI	$\text{AWMSI} = \frac{\sum_{i=1}^{i=N} p_i/4\sqrt{s_i}}{N} \times \frac{s_i}{\sum_{i=1}^{i=N} s_i}$	Where s_i and p_i are the area and perimeter of patch i, and N is the total number of patches
Area weighted mean patch fractal dimension	AWMPFD	$\text{AWMPFD} = \frac{\sum_{i=1}^{i=N} 2\ln 0.25 p_i/\ln s_i}{N} \times \frac{s_i}{\sum_{i=1}^{i=N} s_i}$	Where s_i and p_i are the area and perimeter of patch i, and N is the total number of patches
Centrality	Centrality	$\text{Centrality} = \frac{\sum_{i=1}^{N-1} D_i/N-1}{R} = \frac{\sum_{i=1}^{n-1} D_i/N-1}{\sqrt{S/\pi}}$	Where D_i is the distance of centroid of patch i to centroid of the largest patch, N is the total number of patches, R is the radius of a circle with area of s, and s is summarization area of all patches
Compactness index	CI	$\text{CI} = \frac{\sum_i P_i/p_i}{N^2} = \frac{\sum_i 2\pi\sqrt{s_i/\pi}/p_i}{N^2}$	s_i and p_i are the area and perimeter of patch i, P_i is the perimeter of a circle with the area of s_i and N is the total number of patches
Compactness index of the largest patch	CILP	$\text{CILP} = \frac{2\pi\sqrt{s/\pi}}{p}$	Where s and p are the area and perimeter of largest patch
Ratio of open space	ROS	$\text{ROS} = \frac{S'}{S} \times 100\%$	Where s is the summarization area of all "holes" inside the extracted urban area, s is summarization area of all the patches
Density	Density	$\text{Density} = \frac{T}{S}$	Where T is the city's total population, S is summarization area of all the patches
Purchasing power parity	PPP	Definition from (UNDP, 2001)	Gross domestic product per capita
Telephone lines/1000 people	TELP	Definition from (World Bank, 2000)	National telephone lines ownership
Vehicles/1000 population	VEHPOP	Definition from (World Bank, 2000)	National vehicles ownership

fore, centrality in this research measures the overall shape of the city, i.e. whether it is elongated or circular. The more elongated the overall city shape is, the bigger the centrality index; and vice versa.

2.2.3. Compactness (Fig. 2c)

The compactness index (CI) measures not only the individual patch shape but also the fragmentation of the overall urban landscape (Li and Yeh, 2004). The more regular the patch shape and the smaller the patch number, the bigger the CI value. As it was noticed that the largest patch often accounts for the bulk of the total urban area, especially for cities of developing countries, the compactness index of the largest patch (CILP) which mainly represent the overall shape of the urban centre, was also calculated.

2.2.4. Porosity (Fig. 2d)

A further indicator of "porosity" measures the ratio of open space compared to the total urban area. As a further end of

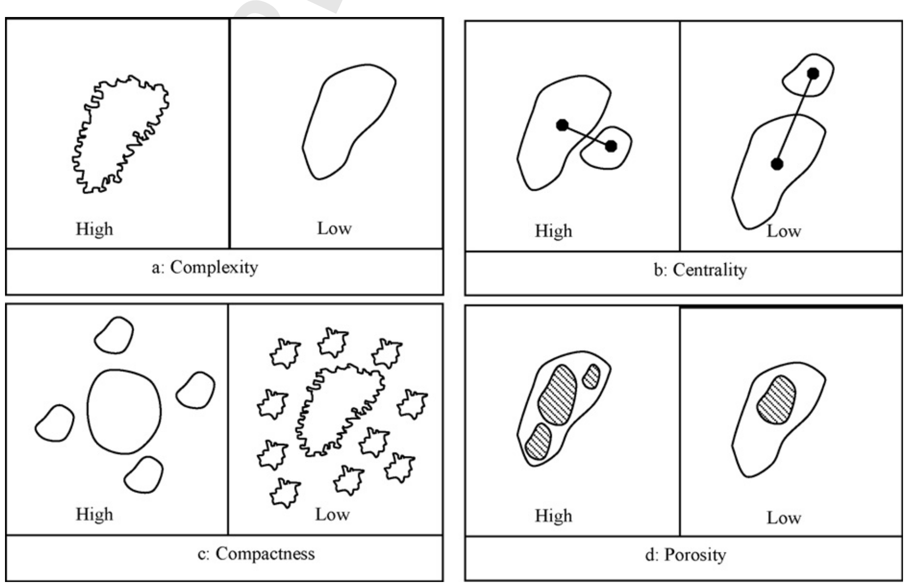

Fig. 2. Schematic map of spatial metrics.

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planning that is linked to arguments against sprawl (Galster et al., 2001), open space is crucial both as an amenity for residents and for the sustainability of cities. The areas of vegetation and water bodies which appeared as unclassified blank areas in the classified images, amount in effect to "holes" of open space within the urban area. The indicator of porosity measures the total area of these "holes" in relation to the calculated entire urbanized area. This indicator of porosity is also designated the "ratio of open space" (ROS).

2.2.5. Density

Finally, population density measures a further generally recognized dimension of compactness or sprawl. Density was calculated by comparing the population of the urban agglomeration to the extracted urban area. The urban population data used here comes from "The 2003 Revision Population Database" figures (UN, 2003) for the year 2000, within 1 year of the satellite images. Despite the cross-checks undertaken to identify urban boundaries in this research, the administrative units used to calculate population data in the UN figures may still not coincide precisely with the physical boundaries used here. For the broad global kind of comparison undertaken in this research, we hold that this data nonetheless offers a meaningful point of reference.

Some spatial metrics such as AWMSI and AWMPFD were obtained by a public domain landscape analysis tool, Patch Analyst (Rempel, 2004). Others, such as CI, CILP, Centrality and ROS, were obtained through the user-developed VBA program in ArcGIS.

3. Results

3.1. Comparison among developed and developing countries

Comparisons of means and *T* tests on the spatial metrics largely manifested the broad differences in urban form between the developing and developed worlds (Table 2). Except Centrality, all the other spatial metrics in the cities of developing regions were significantly (at 95% confidence interval) different from those in developed cities. Generally, the cities of developing regions exhibit the least complex, most compact, least porous, and densest urban forms. Cities of developed regions display diametrically opposed tendencies.

3.2. Comparison among regions (Fig. 3)

Comparison of spatial metrics between the various regions enabled a more detailed view of how urban form varies. In this stage, the analysis separated out three developed regions of the world (US, Australia/New Zealand (AU), and Europe (EU)) from the two developing ones (Asia, Latin America (LA)). Since Japan during the 1990s was indisputably a developed rather than a transitional or developing country, and had followed a path of urban development analogous to that of parts of Europe (see Discussion), Japanese cities were grouped with European ones. Although the results revealed significant variations within both developing and developed regions, the greater contrasts between them overwhelmed these other differences.

Table 2
T test for the means between developed country cities and developing country cities

Group		Mean	S.D.		Levene's test for equality of variances		*T* test for equality of means		
					F	Sig.	*T*	d.f.	Sig. (two-tailed)
AWMSI	Developing	65.3400	36.39159	Equal variances assumed	4.788	.032	3.990	75	.000
	Developed	40.0723	19.04173	Equal variances not assumed			3.509	39.266	.001
AWMPFD	Developing	1.5280	.03440	Equal variances assumed	.599	.441	2.997	75	.004
	Developed	1.5045	.03284	Equal variances not assumed			2.966	59.804	.004
Centrality	Developing	128.93	18.903	Equal variances assumed	1.798	.184	1.597	75	.115
	Developed	122.49	16.157	Equal variances not assumed			1.542	54.835	.129
CI	Developing	.0016919	.0044859	Equal variances assumed	2.317	.132	−2.328	75	.023
	Developed	.0039736	.0039980	Equal variances not assumed			−2.269	56.676	.027
CILP	Developing	.0161760	.00887381	Equal variances assumed	3.214	.077	−4.457	75	.000
	Developed	.0268291	.01099504	Equal variances not assumed			−4.673	70.814	.000
ROS	Developing	26.583	13.0218	Equal variances assumed	6.457	.013	4.012	75	.000
	Developed	17.061	7.8273	Equal variances not assumed			3.610	42.494	.001
Density	Developing	5009.57	3886.304	Equal variances assumed	13.846	.000	−5.746	75	.000
	Developed	14970.55	8955.293	Equal variances not assumed			−6.701	67.788	.000

Note: number of developed country cities is 30, while developing countries cities 47). (AWMSI: area weighted mean shape index; AWMPFD: area weighted mean patch fractal dimension; CI: compactness index; CILP: compactness index of the largest patch; ROS: ratio of open space.

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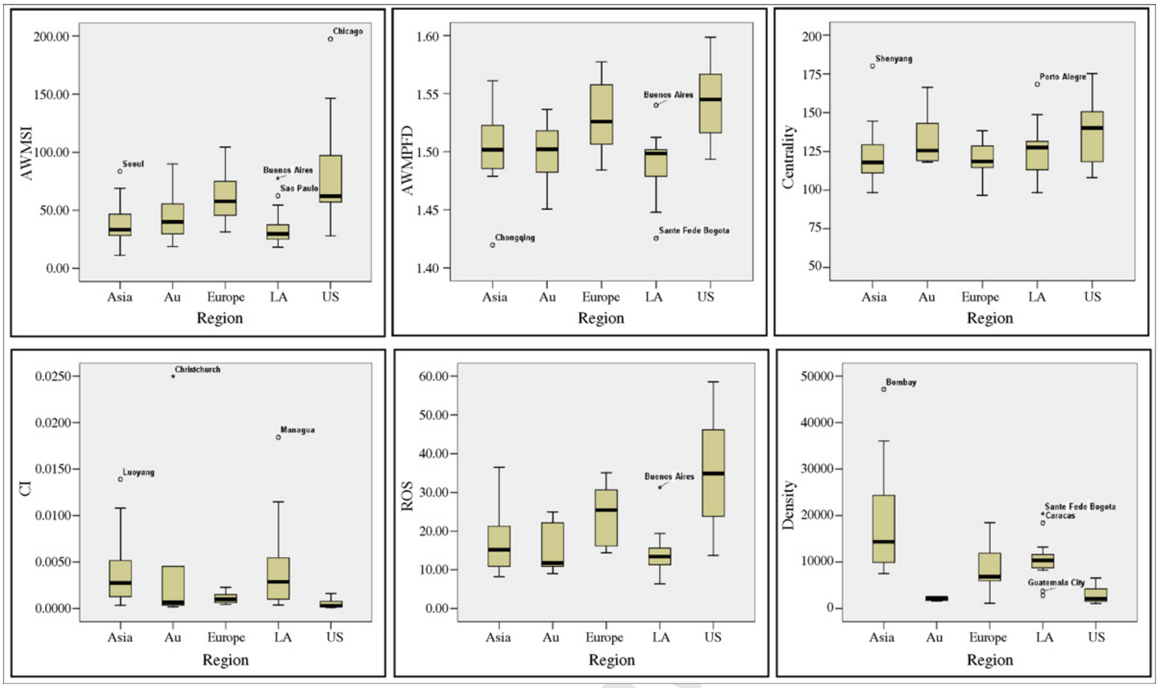

Fig. 3. Comparison of spatial metrics across regions. (AWMSI: area weighted mean shape index; AWMPFD: area weighted mean patch fractal dimension; CI: compactness index; ROS: ratio of open space; density: population density; AU: Australia (New Nealand); LA: Latin Amercia; US: United States). The length of the box represents the difference between the 25th and 75th percentiles. The larger the box, the greater the spread of the data. The horizontal line inside the box represents the median. Dot and star labels symbolize outliers or extreme cases. (*Note*: Japanese cities are in European group).

Asian cities manifest the densest populations, followed by Latin American cities. Both regional averages exceed 100 people per hectare. Cities in both regions are also the most compact, as measured by the CI and CILP. The shapes of both Asian and Latin American cities display much greater regularity on average than the European or US cities. Both the shape and the fractal indices demonstrate the smaller numbers there. Only the Centrality, which here measures the lack of centrality, diverges from this pattern. Asian cities rank last in centrality, with the most centralized patterns of settlement. The rank of Latin American cities according to this indicator, which is higher than in either European or Australian cities, may be skewed by the large size of the central patches there. Yet open space is considerably lower in Latin American cities than in Asian ones, and in both regions much lower than in Europe, Japan or the US.

The European and Japanese cities have moderate densities by comparison with US ones, along with greater centrality, compactness, and regularity and less open space. On average, however, both European and US cities are considerably more irregular in form, less densely populated, and less compact than

Table 3
Correlation analysis among spatial metrics ($N = 77$)

		AWMSI	AWMPFD	Centrality	CI	CILP	ROS	Density
AWMSI	Pearson correlation	1						
	Sig. (two-tailed)							
AWMPFD	Pearson correlation	.799**	1					
	Sig. (two-tailed)	.000						
Centrality	Pearson correlation	−.044	.020	1				
	Sig. (two-tailed)	.707	.865					
CI	Pearson correlation	−.434**	−.457**	−.193	1			
	Sig. (two-tailed)	.000	.000	.092				
CILP	Pearson correlation	−.768**	−.865**	−.077	.682**	1		
	Sig. (two-tailed)	.000	.000	.508	.000			
ROS	Pearson correlation	.779**	.807**	.093	−.448**	−.708**	1	
	Sig. (two-tailed)	.000	.000	.419	.000	.000		
Density	Pearson correlation	−.312**	−.208	−.292*	.153	.336**	−.298**	1
	Sig. (two-tailed)	.006	.070	.010	.184	.003	.008	

AWMSI: area weighted mean shape index; AWMPFD: area weighted mean patch fractal dimension; CI: compactness index; CILP: compactness index of the largest patch; ROS: ratio of open space.
** Correlation is significant at the 0.01 level (two-tailed).
* Correlation is significant at the 0.05 level (two-tailed).

their Asian and Latin American counterparts. Cities in both of these more developed regions also count larger proportions of open space. The Australian and New Zealand cities furnish what might seem a partial exception to the overall pattern of differences between developing and developed regions. These cities share low compactness and density with US counterparts, but forms of urban boundaries with European counterparts. Even here, however, the extensive open space and the irregularity of the urban boundaries approach or exceed those of the developing regions.

3.3. Relations among the indicators

Correlation analysis shows strong relations among most of the spatial metrics (Table 3). Although AWMPFD and AWMSI represent different dimensions of the landscape complexity, there is a strong positive correlation. Both complexity indices correlate very strongly with the overall compactness (CI) and the compactness of the largest patch (CILP). These relations indicate that compact landscape corresponds to a more regular shape. AWMPFD, AWMSI and CILP correlate very positively with open space as measured by ROS. This suggested that the more fragmented, less compact, and complex the urban landscape mosaic, the larger the open space compared to the total urban area. Another noteworthy point is that Density correlates with AWMSI, CILP and ROS at the 0.01 level, indicating a very close relation among these metrics.

3.4. Reclassification of the cities

Hierarchical cluster analysis showed that all cities can be classified into 4 or 5 groups. Building on this result, four types were designated in the subsequent K-Means cluster analysis. With a few qualifications, the resulting classifications (Tables 4 and 5)

Table 4
City classification based on cluster analysis (continent based)

City form group	Region	Cities	Region	Cities
1	Asia	Beijing	Europe	Berlin
	Asia	Chengdu	Europe	Milan
	Asia	Fuzhou	Europe	Madrid
	Asia	Guangzhou	Europe	Kiev
	Asia	Hangzhou	Latin America	Buenos Aires
	Asia	Kunming	Latin America	Cordoba City
	Asia	Luoyang	Latin America	Porto Alegre
	Asia	Nanjing	Latin America	Rio DeJaneiro
	Asia	Shenyang	Latin America	Sao Paulo
	Asia	Shijiazhuang	Latin America	Santiago
	Asia	Zhengzhou	Latin America	San Salvador
	Asia	Tokyo	Latin America	Tegucigalpa
	Asia	Pusan	Latin America	Guadalajara
	Asia	Seoul	Latin America	Mexico City
	Asia	Kaohsiung	Latin America	Monterrey
	Asia	Taipei	Latin America	Managua
	Europe	Lyon	Latin America	Montevideo
2	Asia	Calcutta	Asia	Kanpur
	Asia	Chennai-madras	Asia	Bombay
3	Asia	Chongqing	Asia	Nagpur
	Asia	Shanghai	Asia	New Delhi
	Asia	Tianjin	Europe	St. Petersburg
	Asia	Ahmedabad	Latin America	Sante Fede
				Bogota
	Asia	Bangalore	Latin America	Caracas
	Asia	Hyderabad		
4	Asia	Osaka	Latin America	Quito
	Australia	Melbourne	Latin America	Guatemala City
	Australia	Perth	U.S.	Baltimore
	Australia	Sydney	U.S.	Boston
	Australia	Auckland	U.S.	Chicago
	Australia	Christchurch	U.S.	Dallas
	Europe	Paris	U.S.	Denver
	Europe	Hamburg	U.S.	Little Rock
	Europe	Rome	U.S.	Milwaukee
	Europe	Moscow	U.S.	New Orleans
	Europe	Barcelona	U.S.	Oklahoma City
	Europe	Glasgow	U.S.	Phoenix
	Europe	London	U.S.	Seattle
	Europe	Manchester	U.S.	Washington

Note: New Zealand cities are classified with Australian cities.

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Table 5
Statistics for each of the spatial metrics by city classification

Groups		Z_{score}						
		AWMSI	AWMPFD	Centrality	CI	CILP	ROS	Density
1	Mean	−.2388	−.1019	.0245	.1695	.1316	−.2000	−.0493
	N	34	34	34	34	34	34	34
	S.D.	.6006	.8148	.9589	1.0071	.8002	.7126	.23071
2	Mean	−.6031	−.5418	−.6480	.5912	.7806	−.7319	2.8226
	N	4	4	4	4	4	4	4
	S.D.	.3408	.7044	.6864	.8225	.7783	.5497	.8936
3	Mean	−.3921	−.2800	−.3524	.03820	.5678	−.2665	1.2637
	N	11	11	11	11	11	11	11
	S.D.	.6879	1.4039	.8545	.6441	1.3853	.7703	.3298
4	Mean	.5302	.3111	.2013	−.3053	−.4944	.4521	−.8398
	N	28	28	28	28	28	28	28
	S.D.	1.3061	1.0146	1.1012	1.0775	.8703	1.2531	.2355
Total	Mean	.00000	.00000	.00000	.00000	.00000	.00000	.00000
	N	77	77	77	77	77	77	77
	S.D.	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000

See Table 4 for key.

reaffirmed broad contrasts between the urban forms of developed and developing world cities.

The first cluster includes a set of cities distinguished by moderate centrality, density, complexity, centrality and a moderately low level of open space. This first group combines most Asian cities and Latin American cities. In addition, all the Korean cities and Taiwan cities are allocated into this group. Although there are no US or Australian cities in this group, there are a number of European cities, i.e. Lyon, Berlin, Milan, Madrid and Kiev, along with Tokyo of Japan.

It is in the second and third groups that the developing world cities consistently exceed the indicators for urban form in developed countries. Centrality, centralization and density are all the highest. Complexity and open space, especially in the second group, are the lowest. Interestingly, all the Indian cities are in the second and third groups. Moreover, the second group includes only four Indian cities. Most cities in the third are Indian cities as well, and three Chinese and two Latin American cities are also in this category. Only one European city, the Russian city of St. Petersburg, falls into the group.

The fourth group includes the most characteristic cities of the developed world. Centrality, density and centralization are significantly lower than in the other groups. Open space averages much higher. Contrary to what the transatlantic comparative literature suggests, all of the US and Australian (AU) cities as well as most of the European cities aggregate into this single group. The Japanese city of Osaka falls here as well. Two outliers are the Latin American cities Quito and Guatemala City.

3.5. Correlations between spatial metrics and socio-economic factors

All of the spatial metrics except for Centrality correlate significantly with at least two of the three socio-economic variables. AWMSI, CILP and ROS manifest an especially positive correlation coefficient with all three socio-economic variables. The

Table 6
Correlations analysis between spatial and socio-economical indicators

		AWMSI	AWMPFD	Centrality	CI	CILP	ROS	Density
TELP	Pearson correlation	.605**	.388*	.141	−.441*	−.573**	.523**	−.465*
	Sig. (two-tailed)	.001	.045	.483	.021	.002	.005	.015
PPP	Pearson correlation	.571**	.340	.128	−.402*	−.541**	.473*	−.460*
	Sig. (two-tailed)	.002	.082	.525	.037	.004	.013	.016
VEHPOP	Pearson correlation	.535**	.405*	.180	−.293	−.526**	.512**	−.498**
	Sig. (two-tailed)	.004	.036	.369	.137	.005	.006	.008

AWMSI: area weighted mean shape index; AWMPFD: area weighted mean patch fractal dimension; CI: compactness index; CILP: compactness index of the largest patch; ROS: ratio of open space; TELP: telephone lines/1000 people; PPP: purchasing power parity; VEHPOP: vehicles/1000 population.
Note: As the socio-economic indicators are currently only available by countries, the spatial metrics also use the avearge value for each country. Thus, the total country number for analysis is 27.
** Correlation is significant at the 0.01 level (two-tailed).
* Correlation is significant at the 0.05 level (two-tailed).

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higher the average income and telephone and vehicle popularity the higher the ratio of the open space compare to the total urban area (ROS) and the irregularity and the complexity of the urban landscape (AWMSI) (Table 6). Density and CILP also demonstrate rather strong negative correlations with the three socio-economic indicators.

4. Discussion

Alongside physical factors like geographical location, topography, water bodies and coastlines, regional patterns of economic, political and social development bear a well-established relation to urban form (Berry, 1973; Hawley, 1986; Hall, 1997). This section elaborates how these influences have contributed to the contemporary contrasts in urban form.

4.1. Urban form and national levels of development

The cross-sectional correlations between urban forms and indicators for national levels of development confirm the large difference that national wealth makes (Table 6). Higher purchasing power correlates positively with more complex landscapes and larger proportions of open space, and negatively with Density and Compactness. This is not difficult to understand as wealthier people can afford more private motor vehicles, and wealthier countries can afford more highways, higher purchasing power results in higher levels of motorization. In most developed countries, and especially in the US and Australia, high motorization contributes directly to the ease of living in the outlying suburban area. As the correlations show, higher motorization is associated with low density, a fragmented urban fringe (both less compact in the center and more complex) and abundant open space. On the contrary, under conditions of low motorization, residents of cities in developing countries cannot live far from their working place which is normally in the inner city. The result is more compact urban form.

Analysts have disagreed as to the effects of communications technology on urban form. While Berry (1973) and Fishman (1990) argued that the modern communication spurs urban decentralization, others (Gottmann, 1977; Hawley, 1986; Guillespie, 1992; Hall, 1997, 2002) contend that communications technology fosters a counter-process of concentration in CBD or other forms of urban nodality. Globally, this research accords with the first of these contentions as the number of telephone lines per capita correlates positively with more complex urban form and open space, and negatively with density and compactness (Table 6).

One noteworthy point is that Centrality did not show a significant correlation with the socio-economic variables. This may be due to the increasingly significant role of transportation networks in the evolution of urban form. As the “skeleton” or “framework” of the city, the transportation network essentially directs or guides urban development. In contemporary cities urban development commonly follows arterial roads, in what is known as “ribbon” or “strip” development in US and European cities. This kind of development alters the traditional monocentric urban form, and probably contributes to the insensitive correlation between centrality and the socio-economic indicators.

4.2. Historical trajectories and visual evidence

A full explanation of the regional contrasts in urban form must look beyond contemporary cross-sectional comparison to the cumulative effects of historical influences. Early settlement, industrialization, land ownership, planning, regulation, and infrastructure development have exerted distinct influences on urban growth. Satellite images from a sampling of urban regions manifest not only the broad differences between these legacies in developed and developing countries, but an array of more nuanced contrasts.

The cities of the US and Australia manifest the dispersed, irregular settlement identified with urban sprawl most obviously. In both countries, urban structures date only from the eighteenth or nineteenth centuries. Urban expansion was instead a product of white settlement and the suppression of indigenous groups, and benefited from cheap land and building materials (Jackson, 1985; Gipps et al., 1997). Each country experienced relatively early industrialization, as a middle class acquired considerable resources to invest in exurban property. From the early twentieth century, institutions for land ownership and land use regulation as well as the physical infrastructure of roads and transit were present to support development beyond the urban periphery (Johnson, 1994; Freestone and Murphy, 1996; Troy, 1996). As a result, an extensive and fragmented settlement pattern in each country now makes it difficult to distinguish the core urban area from the surrounding area. Nevertheless, the US and Australian cities show different characteristics in the suburban area. Especially in the urban fringe area, settlement of US cities is characterized by the winding streets and cul-de-sacs (Fig. 4a). In Australian cities the fringe areas display only a mass of tiny patches without the same obvious, circuitous network of roads (Fig. 4b). Although all cities in Australia and New Zealand are allocated in one group in the cluster analysis, the satellite images also show very distinct spatial differences between these two countries. The three Australian cities resemble the dispersed and extensive US pattern. The two New Zealand cities (i.e. Auckland and Christchurch) share features with traditional compact European cities. This anomaly may be attributable to the smaller size of the two cities as well as the mountainous topography and the coastal line surrounding them.

Legacies from centuries of urban development in Europe and Japan have generally produced more compact urban regions than in the US and Australia (Gottmann, 1961; Vance, 1990). Urban settlement dated there back much earlier, and later urban development built on the resulting legacies. Planning and land use regulation often directed development during the age of urban expansion, producing bigger and denser urban cores than the US and Australia cities and large-scale, more regular settlement in the urban periphery (Commission of European Community(CEC), 1990; 60; De Roo and Miller, 2000; Yokohari et al., 2000) (Fig. 4c and 4d). Especially in the latter half of the twentieth century, however, the same

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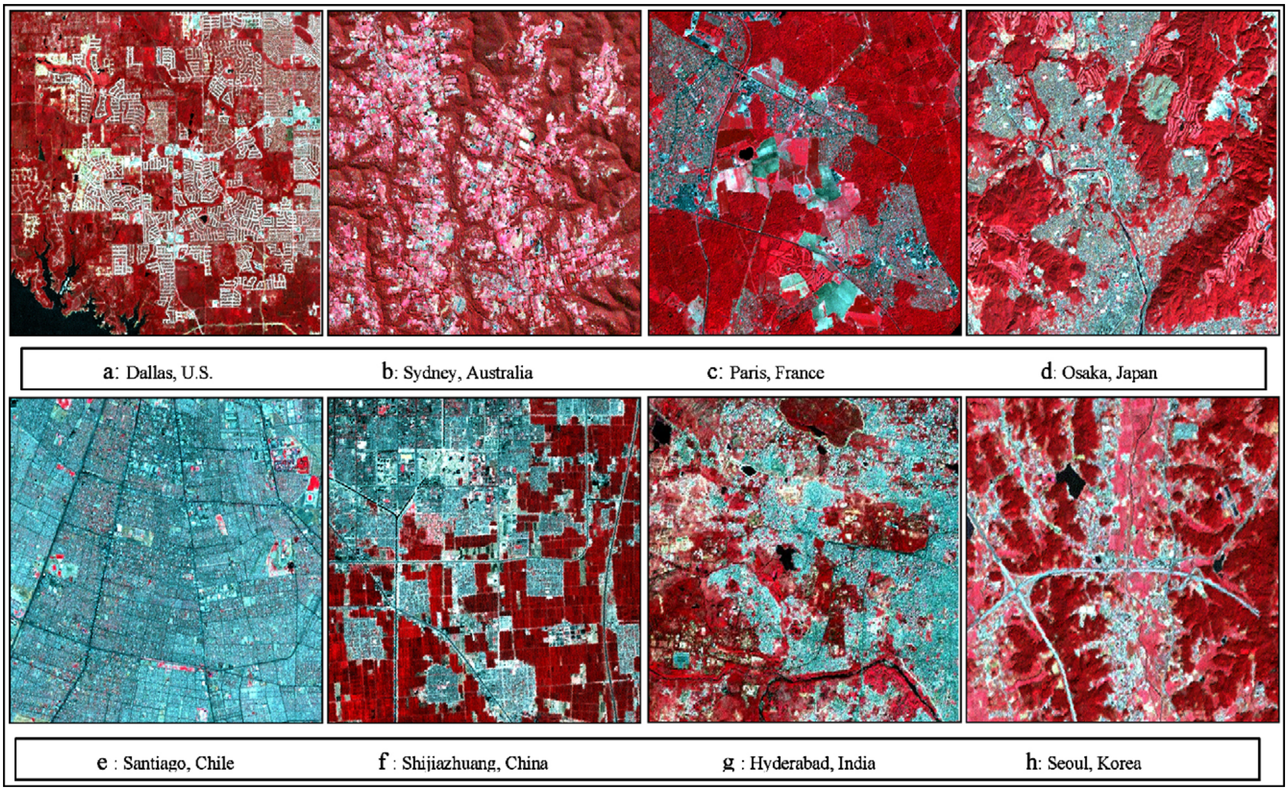

Fig. 4. Examples of urban forms across regions. Settlement of US cities in the fringe area is characterized by the cul-des-sac (Fig. 4a). Australian cities display only a mass of tiny patches without the same circuitous network of roads (Fig. 4b). Europe and Japan evolved the bigger and more regular settlement in the urban periphery (Fig. 4c and d). Latin American cities have the most compact and densest urban core areas, and the radial and concentric road system (Fig. 4e). Cities in Asian countries vary more widely in form in the fringe area. For most Chinese cities, the separation of urban and rural land uses is very clear (Fig. 4f). India cites have a much more convoluted and irregular fringe (Fig. 4g). In the peripheries of Korea cities, mixture of urban with rural land is obvious (Fig. 4h). (*Note*: Scales roughly ranges between 1:40,000 and 1:60,000).

institutional rules of zoning and property ownership, the same infrastructure development and the same middle class consumption as in the US and Australia fostered parallel urban expansion (Dargay and Gately, 1997; Giuliano, 1999; Giuliano and Narayan, 2003). As in the US and Australia, suburban neighborhoods now account for a large proportion of the city area in most European cities (Organisation for Economic Co-operation and Development (OECD), 2000; Hoffmann-Martinot and Sellers, 2005).

In the eastern and southern regions of the European periphery, extensive urban settlement came significantly later. Into the twentieth century as well, trajectories here diverged from those in Western Europe (Hohenberg and Lees, 1996). In central European cities like Berlin as well as in Eastern Europe and Russia like and Kiev and St. Petersburg, state socialist control of land ownership limited exurban development to large-scale satellite cities. Across much of southern Europe like Madrid as well, fragmented land ownership, limited economic development, insufficient physical infrastructure and traditional governance institutions limited development on urban fringe (Molotch, 1993). Milan and Lyon appear also to reflect a denser, centralized pattern of urban development consistent with expectations for southern Europe. All these explained why most of these cities agglomerated together in the cluster analysis.

Latin American cities generally have the most compact and densest urban core areas (Fig. 4e). This centralization, along with a radial and concentric road system indicative of influences from European planning which take notions of compactness and density to extremes (Amato, 1970; Hardoy, 1990; Diego and Dear, 1998). But most Asian cities are also compact and dense, with a dominant large core area (Choe, 2004; Sorensen, 2004). Cities in Asian countries vary more widely in form, especially on the urban fringes. Outside the core urban area in most Chinese cities, where Communist policies have imposed restrictions on private land development and restricted migration to the urban areas, the separation of urban and rural land uses is very clear (Fig. 4f). In India, where neither European planning legacies nor state policies have shaped urban development in these ways, cites have a much more convoluted and irregular fringe (Fig. 4g). In Korea, where the authoritarian regime of the 1970s instituted strict controls on exurban land use that remain in effect, peripheries mix urban with rural land much like in Japan (Yokohari et al., 2000) (Fig. 4h).

5. Conclusion

Remote sensing data and GIS open up a new perspective on urban form. The comparative analysis these methods enable is at once more global and more systematic than what was possible before. In the context of such a wider comparison with cities in the developing world, the familiar but limited variations within the developed world appear in a new light. Both the regional averages and the individual patterns in these spatial indicators confirm the profound effects from contemporary levels of development and the historical legacies linked to them. The compactness, density and regularity of urban areas in developing regions generally exceed the levels throughout developed countries. Although European and Japanese cities display more centralized, more compact, denser, and less irregular forms with than US counterparts, developed regions in general feature higher levels of sprawl than the developing areas of either Asia or Latin America.

Cluster analysis based on spatial indicators confirms the broad lines of this analysis, but also qualifies it in sometimes unexpected ways. Despite the differences between New Zealand cities and US or Australian ones, the clusters suggest that these can be assigned to one group. European cities, especially in the western and northern areas of the Continent, appear more like US and Australian cities than contemporary transatlantic debates usually suggest. Although Chinese and Indian cities share commonalities as Asian cities, most remain sufficiently distinct to fall into different cluster types. Latin American cities resembled Asian cities, especially Chinese cities stand in stark contrast to other researchers' conclusion that Latin American cities are more inclined towards US cities in recent years (Gilbert, 1994).

Future research on these patterns may benefit from several types of improvements and refinements. First, socio-economic data that take account of the within-country variations could also account more fully for the variations we have found. Most of these data are currently only available by countries, leaving all cities in each country with an identical value. Yet increasingly, as the differences between cities in the backward hinterlands and developed coastal areas of China exemplify, cities within a country vary greatly in income, in ownership of vehicles and telephones, and in urban form itself. Second, improvements to the spatial metrics can also improve the results. UN demography data, for instance, derive from administrative boundaries that sometimes only partly correspond to the physical boundaries remote sensing data suggest. More work needs to be done to reconcile the administrative and the physical lines of urban demarcation. Our method for calculating Centrality may also require reformulation. By taking the average distance between dispersed patches and the urban center without accounting for the shape of the largest patch itself, the method here assigns the same value to a city with dispersed patches as to a city with a large central patch. Finally, extension of the sample of cities used here to more comprehensive coverage may also necessitate qualifications to the broad conclusions drawn in this article. For instance, some cities in south-east Asian countries that did not appear in the sample manifest a more mixed and sprawling form than the Indian and Chinese cities that dominate the Asian sample here (Murakami et al., 2005). Application of the indicators and measurements to analyze urban development over time would also help to elaborate how the clear contrasts evident in this study have evolved.

For planners seeking to manage the developing world cities of the twenty-first century, however, the implications of this analysis should already be sobering. The models of the developed world, whether from Europe or from North America, cannot be applied without major adaptations. Disordered as Asian and Latin American cities are, their form bears little resemblance to the sprawl of the United States, Australian and some European cities. From this comparative perspective, more compact form and increasing density may present less a solution to the problems of developing world cities than a symptom and even a primary source of their environmental difficulties. Whatever the merits of different variants among urban form in the developed world, much of the "sprawl" they have in common lies at the source of their comparative environmental quality and livability.

Appendix A

Spatial metrics and selected socio-economic data for each of the cities used in this study. (*Source*: PPP from UNDP, 2001; TELP and VEHPOP from World Bank, 2000, classification criteria of developed and developing countries is based on UN documents (UN, 2005), population data is from UN demography data of 2000)

Appendix A (*Continued*)

Country	Cities	Developmental level	TELP (lines/1000 people)	PPP US$	VEHPOP (vehicles/1000 people)	Urban area (km^2)	Density (person/km^2)	Centrality (%)	AWMSI	AWMPFD	CI	CILP	ROS (%)
Argentina	Buenos Aires	Developing	208.576	11320	181.1	1,216	10350	130	77.66	1.5400	0.000399955	0.011577	31.30
Argentina	Cordoba City	Developing	208.576	11320	181.1	142	10204	131	29.21	1.4990	0.002847926	0.03151	17.66
Australia	Melbourne	Developed	509.3433	25370	601.14	1,527	2257	126	55.51	1.5022	0.00037869	0.016711	11.76
Australia	Perth	Developed	509.3433	25370	601.14	835	1647	166	40.09	1.5180	0.000661905	0.020037	25.01
Australia	Sydney	Developed	509.3433	25370	601.14	2,341	1751	119	89.96	1.5364	0.000174284	0.00936	22.14
Brazil	Porto Alegre	Developing	182.1344	7360	78.9	422	8296	168	26.34	1.4983	0.000642786	0.026145	17.12
Brazil	Rio DeJaneiro	Developing	182.1344	7360	78.9	1,036	10426	149	41.23	1.5087	0.000432981	0.018653	14.66
Brazil	SaoPaulo	Developing	182.1344	7360	78.9	1,472	11617	128	62.46	1.5125	0.000415878	0.014507	15.66
Chile	Santiago	Developing	225.8466	9190	132.7	525	10023	109	24.96	1.4480	0.004889727	0.038979	6.42
China	Beijing	Developing	137.4013	4020	12.4	844	12843	119	57.26	1.5232	0.000688644	0.015288	13.37
China	Chengdu	Developing	137.4013	4020	12.4	318	10360	114	37.05	1.5005	0.008270963	0.026227	10.46
China	Chongqing	Developing	137.4013	4020	12.4	175	24612	139	11.45	1.4197	0.000996344	0.059522	9.14
China	Fuzhou	Developing	137.4013	4020	12.4	121	11575	135	35.25	1.5206	0.004112063	0.026975	17.08
China	Guangzhou	Developing	137.4013	4020	12.4	463	8403	118	57.20	1.5343	0.000759279	0.014189	36.52
China	Hangzhou	Developing	137.4013	4020	12.4	156	11423	111	38.16	1.5211	0.003722537	0.025323	19.88
China	Kunming	Developing	137.4013	4020	12.4	157	10829	117	32.39	1.5036	0.00345615	0.029477	15.18
China	Luoyang	Developing	137.4013	4020	12.4	101	14380	122	26.67	1.4958	0.013909853	0.035002	9.78
China	Nanjing	Developing	137.4013	4020	12.4	190	14431	127	56.93	1.5594	0.002445915	0.015778	22.51
China	Shanghai	Developing	137.4013	4020	12.4	575	22398	111	68.93	1.5609	0.002336388	0.012803	25.18
China	Shenyang	Developing	137.4013	4020	12.4	708	8818	180	48.19	1.5074	0.000976477	0.018061	14.94
China	Shijiazhuang	Developing	137.4013	4020	12.4	211	7582	115	27.04	1.4788	0.007050676	0.032268	12.39
China	Tianjin	Developing	137.4013	4020	12.4	455	20132	144	33.96	1.4935	0.001194153	0.020046	15.54
China	Zhengzhou	Developing	137.4013	4020	12.4	250	8286	107	33.36	1.4938	0.006934233	0.02958	12.22
Colombia	Sante Fede Bogota	Developing	172.2203	7040	51	331	20436	106	18.26	1.4254	0.009645232	0.054523	7.48
Ecuador	Quito	Developing	103.709	3280	49	480	2828	115	35.89	1.4985	0.001022593	0.023792	13.22
ElSalvador	San Salvador	Developing	80.48991	5260	61.3	121	11077	115	23.43	1.4788	0.011322109	0.038863	13.88
France	Lyon	Developed	573.4947	23990	574	166	8200	138	61.39	1.5773	0.000688777	0.012599	28.78
France	Paris	Developed	573.4947	23990	574	1,551	6248	113	56.99	1.5080	0.000748168	0.014745	16.76
Germany	Berlin	Developed	586.7571	25350	529.24	210	15372	135	31.51	1.5020	0.000598676	0.020186	24.05
Germany	Hamburg	Developed	586.7571	25350	529.24	448	5959	118	52.22	1.5261	0.001495173	0.01622	21.76
Guatemala	Guatemala City	Developing	70.51496	4400	52	242	3750	119	25.20	1.4744	0.002876497	0.034828	9.14
Honduras	Tegucigalpa	Developing	44.20645	2830	60.4	106	8782	130	27.80	1.4986	0.011482692	0.035136	11.38
India	Ahmedabad	Developing	26.56299	2840	9.26	202	21939	108	28.35	1.4839	0.005500912	0.03421	9.93
India	Bangalore	Developing	26.56299	2840	9.26	200	27802	98	50.92	1.5435	0.001991589	0.018299	26.86
India	Calcutta	Developing	26.56299	2840	9.26	362	36059	109	28.46	1.4817	0.002742944	0.03258	8.20
India	Chennai-madras	Developing	26.56299	2840	9.26	202	31503	102	45.30	1.5315	0.004836231	0.021682	21.67
India	Hyderabad	Developing	26.56299	2840	9.26	254	21434	111	43.10	1.5222	0.002865826	0.021658	20.91
India	Kanpur	Developing	26.56299	2840	9.26	90	29480	130	21.25	1.4792	0.010793083	0.043067	10.22
India	Bombay	Developing	26.56299	2840	9.26	341	47164	114	33.14	1.4859	0.004166924	0.029061	10.44
India	Nagpur	Developing	26.56299	2840	9.26	83	25078	109	26.44	1.5017	0.006198425	0.035903	13.97
India	New Delhi	Developing	26.56299	2840	9.26	515	24142	129	30.56	1.5134	0.000361207	0.021944	18.89
Italy	Milan	Developed	462.1666	24670	605.9	320	13052	128	63.87	1.5563	0.00100233	0.012729	33.39
Italy	Rome	Developed	462.1666	24670	605.9	392	7003	116	43.10	1.5142	0.001309325	0.017781	14.59
Japan	Osaka	Developed	576.0423	25130	572.4	2,115	5278	97	51.37	1.4845	0.000897005	0.018985	14.95
Japan	Tokyo	Developed	576.0423	25130	572.4	2,705	12734	105	85.02	1.5256	0.001028463	0.011664	15.60
Korea	Pusan	Developing	485.6736	15090	255.1	308	11929	131	29.59	1.4852	0.001364444	0.027864	29.66
Korea	Seoul	Developing	485.6736	15090	255.1	1,045	9487	120	83.56	1.5512	0.000587626	0.010999	24.68
Mexico	Guadalajara	Developing	137.2364	8430	158.9	315	11749	113	37.52	1.5050	0.002316327	0.024626	13.41
Mexico	Mexico City	Developing	137.2364	8430	158.9	1,370	13183	98	54.61	1.5016	0.00110223	0.017041	19.38
Mexico	Monterrey	Developing	137.2364	8430	158.9	381	8571	104	31.07	1.4765	0.003901368	0.031069	11.34
NewZealand	Auckland	Developed	448.0719	19160	696	410	2591	143	29.73	1.4823	0.004537081	0.030329	10.92
NewZealand	Christchurch	Developed	448.0719	19160	696	143	2328	118	18.78	1.4509	0.024996125	0.050445	9.07
Nicaragua	Managua	Developing	30.22088	2450	30.04	95	10648	128	22.78	1.4879	0.01842795	0.04097	9.72

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Country	Cities	Developmental level	TELP (lines/ 1000 people)	PPP US$	VEHPOP (vehicles/ 1000 people)	Urban area (km^2)	Density ($person/km^2$)	Centrality (%)	AWMSI	AWMPFD	CI	CILP	ROS (%)
Russia	Moscow	Developing	226.7525	7100	176.1	1,675	6032	120	104.22	1.5543	0.000447864	0.008101	32.98
Russia	St. Petersburg	Developing	226.7525	7100	176.1	281	18529	120	77.68	1.5771	0.001770477	0.012075	35.09
Spain	Madrid	Developed	433.6351	20150	525.5	459	10976	117	45.98	1.5159	0.002296477	0.017993	28.67
Spain	Barcelona	Developed	433.6351	20150	525.5	647	6772	119	45.74	1.5046	0.00101274	0.020054	25.02
Taiwan	Kaohsiung	Developing	317.4672	12588	297.94	184	7931	137	28.22	1.4875	0.002062945	0.032356	20.72
Taiwan	Taipei	Developing	317.4672	12588	297.94	306	8337	122	30.77	1.4813	0.002063187	0.031455	11.35
Britain	Glasgow	Developed	593.5914	24160	127	463	1222	135	35.41	1.4897	0.000606588	0.022431	14.39
Britain	London	Developed	593.5914	24160	390.8	1,209	6309	118	97.04	1.5591	0.00044271	0.00886	28.05
Britain	Manchester	Developed	593.5914	24160	390.8	450	4943	111	72.09	1.5559	0.00155134	0.013164	25.77
Ukraine	Kiev	Developing	212.1362	4350	390.8	234	11133	129	58.24	1.5687	0.002066423	0.014639	32.50
United States	Baltimore	Developed	670.6312	34320	779.4	683	3049	138	62.62	1.5338	0.000191763	0.011404	33.26
United States	Boston	Developed	670.6312	34320	779.4	612	6615	153	61.96	1.5400	0.000171111	0.010605	40.10
United States	Chicago	Developed	670.6312	34320	779.4	2,904	2869	143	197.36	1.5984	9.01487E-05	0.004326	52.20
United States	Dallas	Developed	670.6312	34320	779.4	2,198	1898	108	146.62	1.5774	0.000178584	0.005909	56.03
United States	Denver	Developed	670.6312	34320	779.4	327	6109	142	61.46	1.5499	0.001201072	0.014598	25.75
United States	Little Rock	Developed	670.6312	34320	779.4	320	1130	148	45.22	1.5201	0.000728684	0.016996	39.99
United States	Milwaukee	Developed	670.6312	34320	779.4	637	2058	111	110.36	1.5873	0.000548149	0.008359	58.58
United States	New Orleans	Developed	670.6312	34320	779.4	451	2237	162	28.19	1.4934	0.001628341	0.030127	13.81
United States	Oklahoma City	Developed	670.6312	34320	779.4	503	1488	129	72.12	1.5556	0.000466768	0.0109	36.45
United States	Phoenix	Developed	670.6312	34320	779.4	1,793	1636	117	52.95	1.5124	0.000814552	0.016625	15.93
United States	Seattle	Developed	670.6312	34320	779.4	2,406	1133	175	61.54	1.5053	9.65398E-05	0.012002	21.97
United States	Washington	Developed	670.6312	34320	779.4	728	5423	120	84.00	1.5560	0.000215514	0.009135	32.74
Uruguay	Montevideo	Developing	278.436	8400	164.56	144	9209	134	29.76	1.4979	0.005475705	0.032469	14.93
Venezuela	Caracas	Developing	112.7469	5670	87.58	171	18416	132	31.58	1.5006	0.002882625	0.029847	12.90

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