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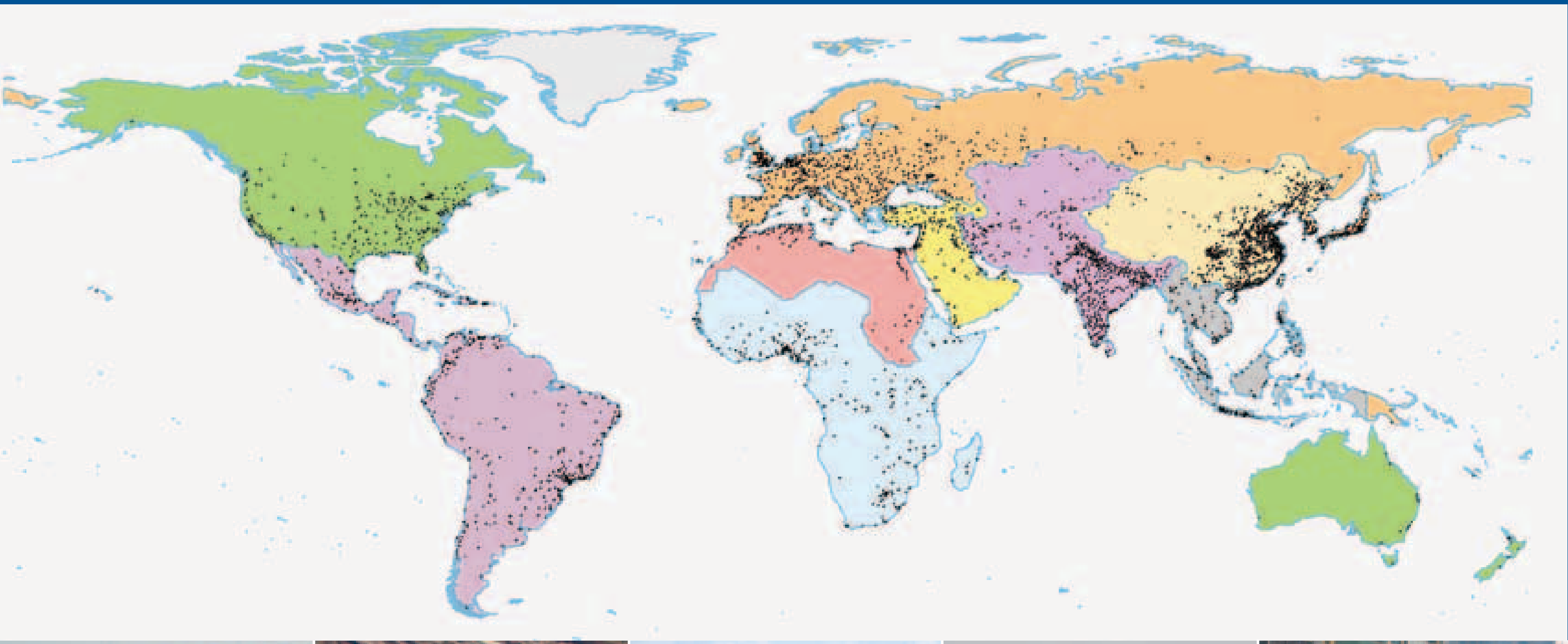
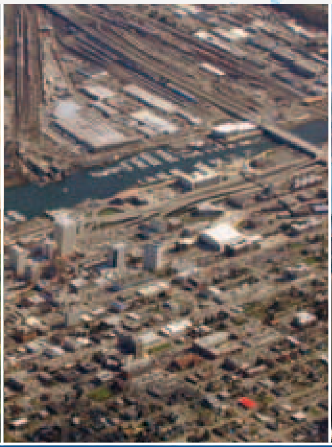
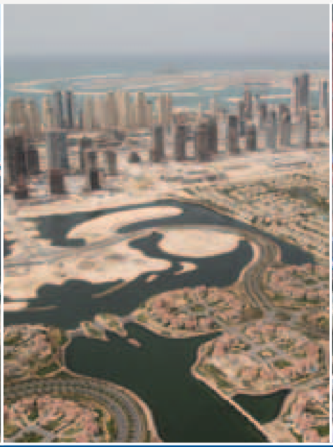
Making Room for a Planet of Cities






SHLOMO ANGEL

with Jason Parent, Daniel L. Civco, and Alejandro M. Blei

Making Room for a Planet of Cities

Shlomo Angel, with Jason Parent, Daniel L. Civco, and Alejandro M. Blei

Policy Focus Report Series

The policy focus report series is published by the Lincoln Institute of Land Policy to address timely public policy issues relating to land use, land markets, and property taxation. Each report is designed to bridge the gap between theory and practice by combining research findings, case studies, and contributions from scholars in a variety of academic disciplines, and from professional practitioners, local officials, and citizens in diverse communities.

About This Report

The authors document the results of a five-year study of global urban expansion, initiated in 2005 with a grant from the World Bank that resulted in the report, *The Dynamics of Global Urban Expansion* (Angel et al. 2005). That initial phase of the study focused on analyzing and comparing satellite images and urban populations in a global sample of 120 cities circa 1990 and 2000. A second phase of the study, with support from the National Science Foundation, involved a survey of housing conditions and the regulatory regimes governing urban expansion in the same sample of 120 cities. The survey was conducted by local consultants in 2006–2007.

The third and fourth phases, with support from NASA (National Aeronautics and Space Administration), Cities Alliance, and the Lincoln Institute of Land Policy, involved several additional steps and resulted in three Institute-sponsored working papers. They present historical research on urban expansion in 20 U.S. cities from 1910 to 2000; historical analysis of a representative global sample of 30 cities from 1800 to 2000; and the analysis of a new global urban land cover map of all 3,646 named large cities with 100,000 people or more in the year 2000 (Angel et al. 2010a; 2010d; 2010e). The complete data sets, with their associated maps and spreadsheets, are available in *The Atlas of Urban Expansion* on the Lincoln Institute Web site at *www.lincolninst.edu/subcenters/atlas-urban-expansion.*

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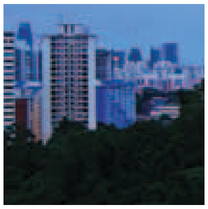
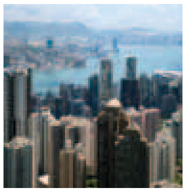








Executive Summary

Urban expansion into the sea, Dubai, United Arab Emirates

The prevailing urban planning paradigm now guiding the expansion of cities and metropolitan areas is premised on the containment of urban sprawl, but containment is not appropriate in rapidly urbanizing countries where most growth in now taking place. Our analysis of the quantitative dimensions of past, present, and future urban land cover suggests a different paradigm—the making room paradigm—as a more realistic strategy for cities and metropolitan regions that need to prepare for their inevitable expansion.

An urban planning strategy that can effectively meet the challenges posed by worldwide urban expansion cannot rely on simply transplanting a containment strategy from one city, where it may be sensible and advisable, to another one, where it may not be, without a deeper understanding of the key spatial dimensions of these cities and their changes over time.

This policy focus report seeks to enrich our understanding of the context in which preparations for urban expansion must take place in cities around the world using empirical data on key parameters that characterize their spatial structure and its changes over time. Carefully selected metrics measured in four new data sets with ArcGIS software now allow us to construct a comprehensive and consistent global and historical perspective on urban expansion. These data sets are:

1. Built-up area maps of a global sample of 120 cities with 100,000 people or more in 1990 and 2000, based on satellite images;
2. Maps of a set of 20 U. S. cities, 1910–2000, using historical population density data at the census tract level in digital maps;

3. Built-up area maps of a representative global sample of 30 cities, 1800–2000, from the set of 120 cities;
4. Urban land cover maps of the universe of 3,646 cities that had populations of 100,000 or more in 2000.

This report examines three discrete attributes of urban spatial structure and their change over time: density, the average population density of the built-up area; fragmentation, the amount of open space in and around cities that is fragmented by their built-up areas; and urban land cover, the total land area occupied by cities. While these attributes are correlated with each other, they measure different phenomena. Measured over time these attributes provide a relatively comprehensive characterization of urban expansion worldwide.

The key research findings can be summarized as follows:

- On average, built-up area densities in developing countries are double those in Europe and Japan, and such densities in Europe and Japan are double those of the United States, Canada, and Australia.
- Average built-up area densities declined by 2 percent per annum between 1990 and 2000 and have been in persistent decline for a century or more.
- Cities have fragmented open spaces in and around them that are equivalent in size to their built-up areas, but the share of fragmented open space within city footprints has declined slowly yet significantly in the 1990s.
- On average, the annual growth rate of urban land cover was twice that of the urban population between 1990 and 2000, and most of the cities studied expanded their built-up area more than 16-fold in the twentieth century.
- At present rates, the world's urban population is expected to double in 43 years while urban land cover will double in only 19 years.
- The urban population of the developing countries is expected to double between 2000 and 2030 while the built-up area of their cities can be expected to triple.

These projections of urban expansion in all regions, especially in developing countries, should give pause to advocates of global urban containment. The report identifies five principal reasons why the containment paradigm is ill-suited for rapidly growing, high-density cities in developing countries: (1) urban growth boundaries that are too tight-fitting; (2) misplaced hopes on infill; (3) unnecessary densification; (4) overreliance on regulation; and (5) undersupply of arterial roads.

The proposed making room paradigm is grounded in the conviction that we need to prepare for the sustainable growth and expansion of cities in rapidly urbanizing countries rather than seek to constrict and contain them. This alternative paradigm consists of four key components: (1) realistic projections of urban land needs; (2) generous metropolitan limits; (3) selective protection of open space; and (4) an arterial grid of roads at one kilometer apart.

This report provides both the conceptual framework and, for the first time, the basic empirical data and quantitative dimensions of past, present, and future urban expansion in cities around the world that are necessary for making minimal preparations for future growth. At the very least, the report lays the foundation for fruitful discussion of the fate of our cities and our planet as we seek to identify and employ appropriate strategies for managing urban expansion at sustainable densities.

CHAPTER 1

Global Urban Expansion: An Empirical Investigation

The theory and practice of urban planning, like many other disciplines, is now globalized, and the prevailing paradigm guiding the planning of cities and metropolitan areas the world over is containment. A growing number of advocates and supporters of containment readily assert that it is in the public interest to contain unrestrained urban expansion, typically decried as sprawl, and to make cities more compact.

These advocates claim that, left to their own devices, cities and metropolitan areas occupy and fragment too much of their surrounding countryside. They are convinced that (1) the current density of urban land is too low and needs to be increased; (2) there is an excessive amount of vacant land within the built-up areas of cities that needs to be filled in; and (3) the land on the urban periphery needs to be left largely undisturbed.

The antisprawl literature, from the popular to the academic, is vast and varied, and it should come as no surprise that containment—also referred to as growth control, growth management, smart growth, or compact cities—has gained in popularity in recent years. It has broad support among environmental groups; municipal officials concerned with the cost of extending urban services; established residents (and financial institutions) who want to maintain high property values; and well-meaning citizens concerned with the fate of our planet.

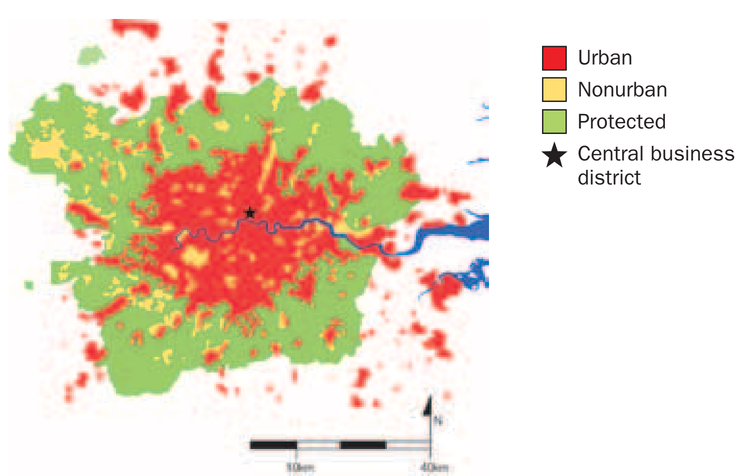
Calls for urban containment are by no means new. In the United Kingdom they date back to the Town and Country Planning Act of 1947 and to London's greenbelt (figure 1.1). In Korea, they date to the 1970s and Seoul's greenbelt (figure 1.2), and in Oregon, they date to 1973 with Portland's urban growth boundary (figure 1.3).

Nevertheless, most cities have largely avoided calls for containment and have expanded rapidly, accommodating more and more people, and occupying broad swaths of the countryside at lower densities as their economies grew and as transport costs declined. Indeed, 28 cities out of a global sample of 30 cities we studied have multiplied their built-up areas at least 16-fold during the twentieth century. They clearly have not been contained.

It may well be that containment is suitable in some cities, where population growth has subsided and where densities are already too low to sustain public transport, yet unsuitable in others, where population growth is still substantial and where higher densities and lower levels of car ownership can sustain public transport.

Containment may be counterproductive in rapidly growing cities by preventing them from preparing adequate room for their

FIGURE 1.1
The London, England Greenbelt, 1973



projected expansion so as to avoid its undesirable outcomes. In short, the decision on whether to contain cities or make room for their expansion must be based on a careful assessment of the empirical evidence, not on ideological positions that may turn out to be unrealistic.

This policy focus report provides, for the first time, the quantitative dimensions of past, present, and future urban expansion and its key attributes in a large number of cities and countries. This global empirical evidence is critical for an informed discussion of plans and policies to manage urban expansion—whether to reverse it, contain it, guide it, let it be, or encourage it.

HOW AND WHY CITIES EXPAND: THE CONCEPTUAL FRAMEWORK

The theoretical foundation for the economic analysis of urban spatial structure in general, and urban expansion in particular, was laid out by Alonso (1964), Mills (1967), and Muth (1969), refined by Wheaton (1976), and later unified by Brueckner (1987). The evidence presented in this report validates the key results of their theoretical insights and confirms the observation of Mills and Tan (1980, 314) that "[t]here are few cases in economics in which such a simple theory leads to so many testable implications."

Box 1.1 introduces the basic elements of this theory and the set of testable hypotheses derived from it. In general, the classical theory predicts that variations in urban land cover, average density, and fragmentation among cities and countries, as well as their rates of change, can be largely explained by variations in city population, household income, buildable land, the cost of agricultural land in the urban periphery, and the cost of urban transport.

Empirical evidence from multiple regression models based on the classical theory and its extensions supports most of these predictions. All in all, the models we examined are robust and able to explain a substantial amount of the variations in urban spatial structure among cities, suggesting that variations in the climate, cultural traditions, or policy environment in different cities may matter less than fundamental economic forces in giving shape to their spatial structure.

FIGURE 1.2
The Seoul, Korea Greenbelt, 1972

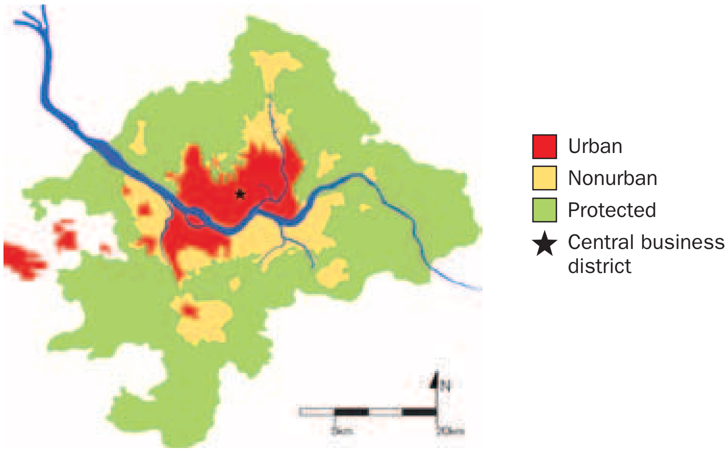
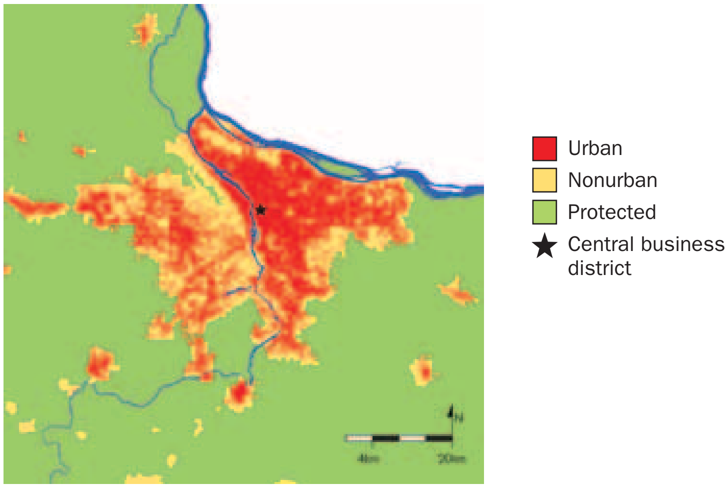


FIGURE 1.3
Portland, Oregon's Urban Growth Boundary, 1973



FIVE KEY ATTRIBUTES OF URBAN SPATIAL STRUCTURE

Our empirical study of urban expansion has benefited from previous efforts to measure urban sprawl while ignoring the negative connotations of that term. The academic literature includes numerous attempts to define and measure sprawl, and there is almost universal consensus on its key manifestations: endless cities, low densities, fuzzy boundaries between city and countryside, a polycentric urban structure, decentralized employment, single-use rather than mixed-use urban expanses, ribbons and commercial strips, scattered development, leapfrogging development, and the fragmentation of open space. Many of these attributes characterize urban expansion everywhere, and quite a few of them can be measured precisely so that we can compare them among cities or in a given city in two periods of time.

Following Galster et al. (2001), we define and measure urban extent and its attributes as *patterns* of urban land use—spatial configurations of a metropolitan area at a point in time—and urban expansion and its attributes as *processes*—changes in the spatial structure of cities over time. Patterns and processes are to be distinguished from the causes that bring about spatial patterns, or from the consequences of such patterns.

We also take these spatial attributes of cities to be a relative rather than an absolute characterization of an urban landscape. In historical terms, the suburban densities of yesteryear—epitomized by the endless suburbs built in the 1940s in and around Los Angeles—may no longer be considered low densities in comparison with the newer subdivisions with large-lot mansions now springing up in many U.S. metropolitan regions.

Five discrete attributes of urban spatial structure can be measured and analyzed

BOX 1.1

Hypotheses Regarding Urban Expansion Derived from the Classical Model

The stylized city in the classical economic model of urban spatial structure is circular, with a single central business district (CBD) surrounded by concentric rings of residences. The households have homogeneous incomes and preferences, and their breadwinners commute to the CBD, where all jobs are concentrated. The theory confirms that, in equilibrium, the price of land will decline while the quantity of housing consumed will increase with distance from the city center. Both land rent and population density will decline with distance from the CBD.

On the periphery, urban housing producers must outbid agricultural users of land to convert land to urban use, and in equilibrium the land rent at the edge of the city must equal the agricultural rent. The entire population of the city must be accommodated in the buildable area inside a circle of a finite radius. The classical theory provides an endogenous solution for the extent of the area that a city occupies and its average density, given the population and its income, the cost of transport, the share of buildable land, and the agricultural rent on the urban periphery.

The solution of the equilibrium equations in this theoretical model of the city yields a number of inequalities that can be translated into several testable hypotheses (Brueckner 1987, 831; 840–844):

- The area of the city will increase when its population increases, when household incomes increase, when transport costs decrease, when the share of buildable land increases, and when agricultural rents on the urban periphery decrease.
- Average density will increase when population increases, when household incomes decrease, when transport costs increase, when the share of buildable land decreases, and when agricultural rents on the urban periphery increase.

Lakewood, a suburb of Los Angeles, California, 1940s

Franklin Township, New Jersey, 2000s

systematically in all cities and countries. Four of these attributes have been used by other researchers to measure sprawl. Measured over time, they provide a relatively comprehensive characterization of urban expansion worldwide.

1. Urban land cover, or urban extent, is typically measured by the total built-up area (or impervious surface) of cities, sometimes including the open spaces captured by their built-up areas and the open spaces on the urban fringe affected by urban development. Sinclair (1967), Brueckner and Fansler (1983), Lowry (1988), and Hasse and Lathrop (2003), for example, define and measure sprawl as the quantity of land converted to urban use.

2. Density, or more precisely average urban population density, is typically measured as the ratio of the total population of

An extension of the classical theory suggests that cities with higher levels of income inequality will occupy more land and have lower densities. Wheaton (1976, 43) shows that when the rich do not obtain housing in the same land market as the poor then "[t]his reduced competition in turn allows the poor to bid somewhat less, expand their land consumption, and improve their situation." This condition exists in cities where a substantial share of the urban population lives in informal settlements, leading to this hypothesis:

- The area of the city will increase and its density will decrease if income inequality is more pronounced and if a larger share of the population inhabits informal settlements.

The classical theory does not allow us to predict why certain cities will be more fragmented than others. In the absence of theoretical results, we assumed that fragmentation is inversely proportional to density.

- Fragmentation will decrease when the city population increases, when household incomes decrease, and when agricultural rents increase.

We also formulated several hypotheses based on anecdotal findings in the literature concerning fragmentation:

- Since cars make it possible to reach all locations at low cost, the higher the level of car ownership, the lower the level of fragmentation.
- Since the presence of ground water makes it possible to locate anywhere, the larger the share of households obtaining water from wells, the higher the level of fragmentation.
- Since informal settlements typically occupy undesirable lands, the higher the share of informal settlements, the lower the level of fragmentation.

The medinah in Fez, Morocco, 2010

Le Corbusier's *Plan Voisin* in Paris, France, 1925

the city to the total built-up area it occupies. Brueckner and Fansler (1983), Brueckner (2000), Civco et al. (2000), Ewing, Pendall, and Chen (2002), Fulton et al. (2001), and El Nasser and Overberg (2001), for example, define and measure sprawl as low density or density decline.

3. Centrality concerns the relative proportion of the population of the city that lives in close proximity to its center rather than in its suburban periphery. It is typically measured by both parameters of the density curve defined by Clark (1951)—its intercept (corresponding to maximum densities at the urban center) and its gradient (the rate of decline in density as distance from the city center increases). Self (1961), Gottman and Harper (1967), Jackson (1975), Kasarda and Redfearn (1975), and Hall (1997), for example, define and measure sprawl as the increasing share of the urban population living in suburbs.

4. Fragmentation, or scattered development, is typically measured by the relative amount and the spatial structure of the open spaces that are fragmented by the noncontiguous expansion of cities into the surrounding countryside. Clawson (1962), Peiser (1989), Weitz and Moore (1998), Carruthers and Ulfarsson (2001), Heim (2001), and Burchfield et al. (2006), for example, define and measure sprawl as noncontiguous, fragmented development.

5. Compactness, or the degree to which the city footprint approximates a circle rather than a tentacle-like shape, is typically measured by a set of compactness metrics (Angel, Parent, and Civco 2010b). To date, no one to our knowledge has proposed measuring sprawl by the compactness of urban footprints, even though it does have an effect on overall accessibility: the more circular the city, the closer its locations are to its center and to one another.

These five attributes do not include some important aspects of urban spatial structure that are often mentioned in the sprawl literature because it is more difficult to obtain comparative global data to study them: e.g., the decentralization of employment (Glaeser and Kahn 2004); polycentric development (Anas, Arnott, and Small 1998; Clawson and Hall 1973); and single-use development (Nelson et al. 1995).

While these attributes are correlated with each other, they measure different phenomena. Cities can suburbanize or expand because of their growing populations, for example, without also experiencing a decline in average density. Similarly, the density of the built-up areas of cities may increase whether fragmentation decreases or increases. The medinah in Fez, Morocco, illustrates high built-up area density and low fragmentation, whereas Le Corbusier's *Plan Voisin* for Paris proposes high built-up area densities and high fragmentation.

METRICS

The unit of investigation in this report is the metropolitan area, typically a central city surrounded by suburbs and secondary cities that form a relatively contiguous whole. Urban land is occupied by urban uses that include all land in residential, commercial, industrial, and office use; land used for transport, parks, and public facilities; protected land; and vacant land. Land in urban use does not include cultivated lands, pasture lands, forests, farms, villages, intercity roads, and nature areas. The terms *city* and *metropolitan area* are used interchangeably.

A central problem involved in measuring the attributes of urban spatial structure concerns a precise and consistent definition of what constitutes the area of the city (Wolman et al. 2005; Parr 2007). Using the administrative area is typically inadequate, both because it can be changed from one day to the next by decree and because it may include large rural areas. For example, in 1999 the administrative area of Beijing (measured in square kilometers as 16,801 km^2) was 11 times larger than its built-up area (1,576 km^2) (figure 1.4).

The built-up area of the city is a much more precise, consistent, and comparable measure of its area, and the analysis of satellite images now allows us to identify built-up areas by impervious surfaces (pavements, rooftops, and compacted soils). We use Landsat imagery with a 30-meter pixel resolution and Mod500 imagery with 463-meter pixel resolution to map the built-up pixels and the open space pixels in and around cities. We then use these digital maps, in combination with population data for the administrative districts encompassing these cities, to calculate most spatial metrics in a consistent manner across cities and countries using geographic information systems (GIS) software.

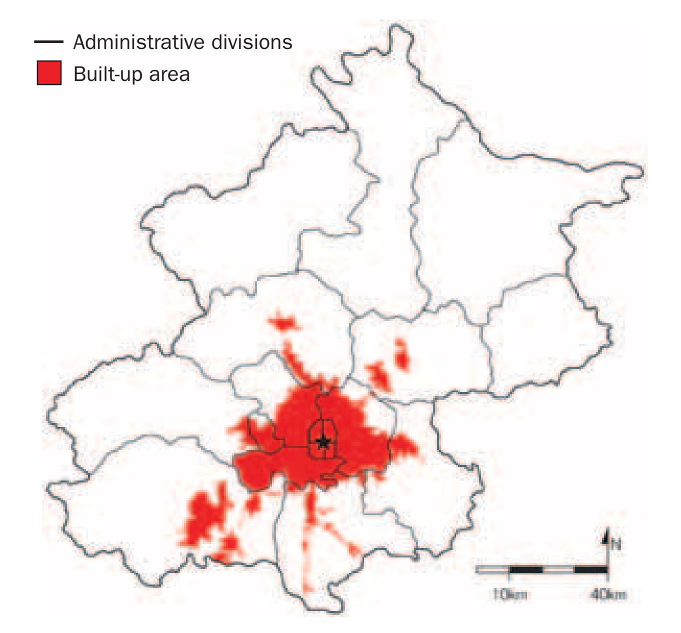
Area, Extent, and Expansion Metrics

The key data used for measuring urban spatial structure are built-up and open space pixels of several types.

- Urban built-up pixels have a majority of built-up pixels in a circle 1 km^2 in area around them (the walking distance circle).
- Suburban built-up pixels have 10–50 percent of built-up pixels within their walking distance circle.
- Rural built-up pixels have less than 10 percent of built-up pixels within their walking distance circle.

Landscape ecology studies maintain that settlements developed near a forest or prairie affect vegetation and wildlife along their edges, often in a belt up to 100 meters in

FIGURE 1.4
The Administrative Divisions and the Built-Up Area of Beijing, China, 1999



Fragmentation on the urban fringe: Where does the city end and the countryside begin?

width (Chen, Franklin, and Spies 1992; Winter, Johnson, and Faaborg 2000; Brand and George 2001). Three metrics are used to characterize fragmentation of development on the urban periphery.

- Fringe open space consists of all open space pixels within 100 meters of urban or suburban pixels.
- Captured open space consists of all open space clusters that are fully surrounded by built-up and fringe open space pixels and are less than 200 hectares in area.
- Exterior open space consists of all fringe open space pixels that are less than 100 meters from the open countryside. It surrounds the entire city footprint.

In the cases where population data can be obtained at the census tract level, we can also define the urban tract area of the city as the set of tracts within the administrative area that have a population density above a certain threshold. The U.S. Census Bureau (2000), for example, defines urban tracts as those with more than 1,000 persons per square mile, or 3.86 persons per hectare. Based on these preliminary definitions, we use three area metrics to measure various attributes of urban spatial structure.

- The built-up area is the set of built-up pixels within the administrative boundary of the city or metropolitan area.
- The city footprint is the set of urban and suburban pixels, their fringe open space pixels, and the captured open spaces these pixels surround.
- The urban tract area is the set of census tracts within the administrative area of the city with a population density greater than 3.86 persons per hectare.

Density, Centrality, Fragmentation, and Compactness Metrics

Three measures of average density are based on the area metrics listed above.

- Built-up area density is the ratio of population within the administrative area of the city and the area of its built-up pixels.
- City footprint density is the ratio of the population within the administrative area of the city and the area of its city footprint.
- Urban tract density is the ratio of the total population and the total area of urban tracts.

Urban tracts contain large amounts of vacant land and, in general, urban tract densities are much lower than built-up area densities and are typically closer in magnitude to city footprint densities. Because the main focus in this report is on comparing densities among cities and on density change over time, the choice of any particular metric for measuring density is not significant, and these metrics will be used interchangeably.

Centrality can be analyzed when detailed maps of census tracts and their associated populations are available. Clark (1951) postulated and showed that urban population densities decline at a constant rate as distance from the city center increases. In the case of Paris (figure 1.5), central density is low because of the proliferation of public, office, and commercial buildings in the city center, and a value was not included in estimating the overall density curve. For Paris in 2000, the gradient of the density curve was -0.103; that is, density declined by 10.3 percent, on average, as distance from the center increased by one kilometer. The density intercept was 236 persons per hectare.

Two metrics are of interest in studying centrality and its change over time.

- The tract density gradient is defined as the slope of the density curve.
- The tract density intercept is defined as the value of the density curve at the Y axis.

Five metrics were used in this study to measure different aspects of fragmentation.

- The openness index is the average share of open space in the walking distance circle around each built-up pixel in the city.
- The city footprint ratio is the ratio of the city footprint and the built-up area.
- Infill is defined as all new development that occurred between two time periods within all the open spaces in the city footprint of the earlier period excluding exterior open space.
- Extension is all new development that occurred between two time periods in contiguous clusters that contained exterior open space in the earlier period and that were not infill.
- Leapfrog development is all new construction that occurred between two prescribed time periods and was built entirely outside the exterior open space of the earlier period.

Finally, two metrics were used to measure the compactness of city footprints. To calculate these metrics we first define the equal-area circle as a circle with an area equal to that of the city footprint centered at the city's center, identified as the location of its city hall (CBD).

- The proximity index is the ratio of the average distance from all points in the equal-area circle to its center and the average distance to the city center from all points in the city footprint.
- The cohesion index is the ratio of the average distance among all points in an equal-area circle and the average distance among all points in the city footprint.

FIGURE 1.5
The Density Curve for Paris, France, 2000

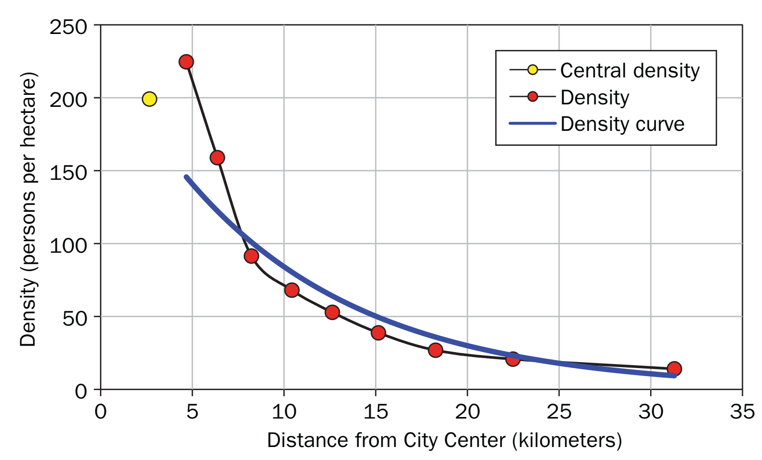
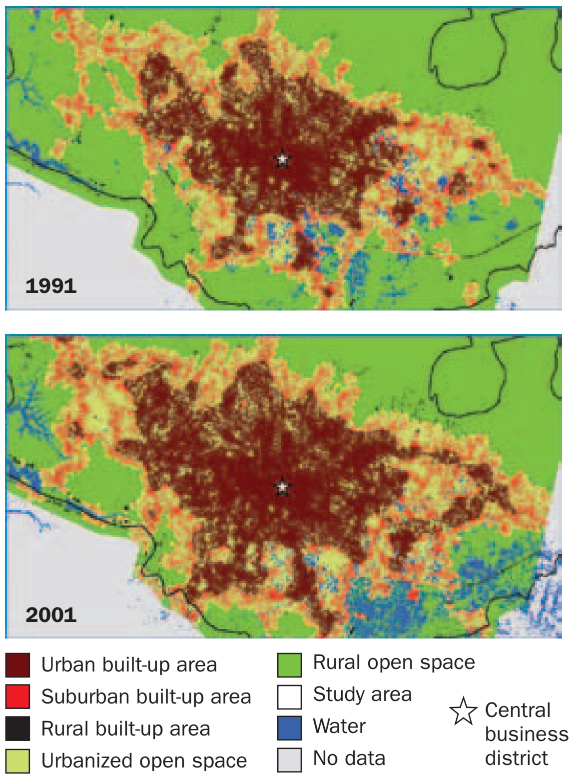


FIGURE 1.6

The City Footprint of Bandung, Indonesia, 1991–2001



The Metrics Applied to Bandung, Indonesia

The city footprints of Bandung in 1991 and 2001 are shown in figure 1.6. In 1991 Bandung had a built-up area of 108 km^2, of which 64 percent was urban, 34 percent was suburban, and 2 percent was rural. Fringe open space added 103.2 km^2 and captured open space added 5.1 km^2 respectively to the built-up area. The city footprint area thus amounted to 217.0 km^2, roughly double its built-up area. In 1991, the built-up area density in Bandung was 274 persons per hectare (p/ha) and its city footprint density was 134 p/ha. The openness index in the city was 0.41 and the city footprint ratio was 2.0. The proximity index for the city was 0.84 and the cohesion index was 0.82.

The area of new development in Bandung between 1991 and 2001 amounted to 45.1 km^2, of which 23 percent was infill, 60 percent was extension, and 17 percent was leapfrog. By 2001, the built-up area density in Bandung declined to 239 p/ha at an annual rate of decline of 1.4 percent, and its city footprint density declined to 128 p/ha at an annual rate of 0.16 percent. Bandung became less dense. Its openness index declined to 0.37 and its city footprint ratio declined to 1.85 as it became less fragmented. Its proximity index increased to 0.87 and its cohesion index increased to 0.86 as the city became more compact.

NEW GLOBAL INFORMATION FOR STUDYING URBAN EXPANSION

Four complementary data sets, three of them using new primary data, were assembled for this study and used to calculate the area, density, centrality, fragmentation, and compactness metrics on a global and historical scale.

The Global Sample of 120 Cities, 1990–2000

This data set of digital maps is based on satellite images of 120 cities and metropolitan areas in two time periods (circa 1990 and 2000). In an earlier study (Angel et al. 2005, chapter 2), we identified a total of 3,945 large cities with populations of 100,000 or more that were home to a total of 2.12 billion people or three-quarters of the world's urban population in the year 2000.

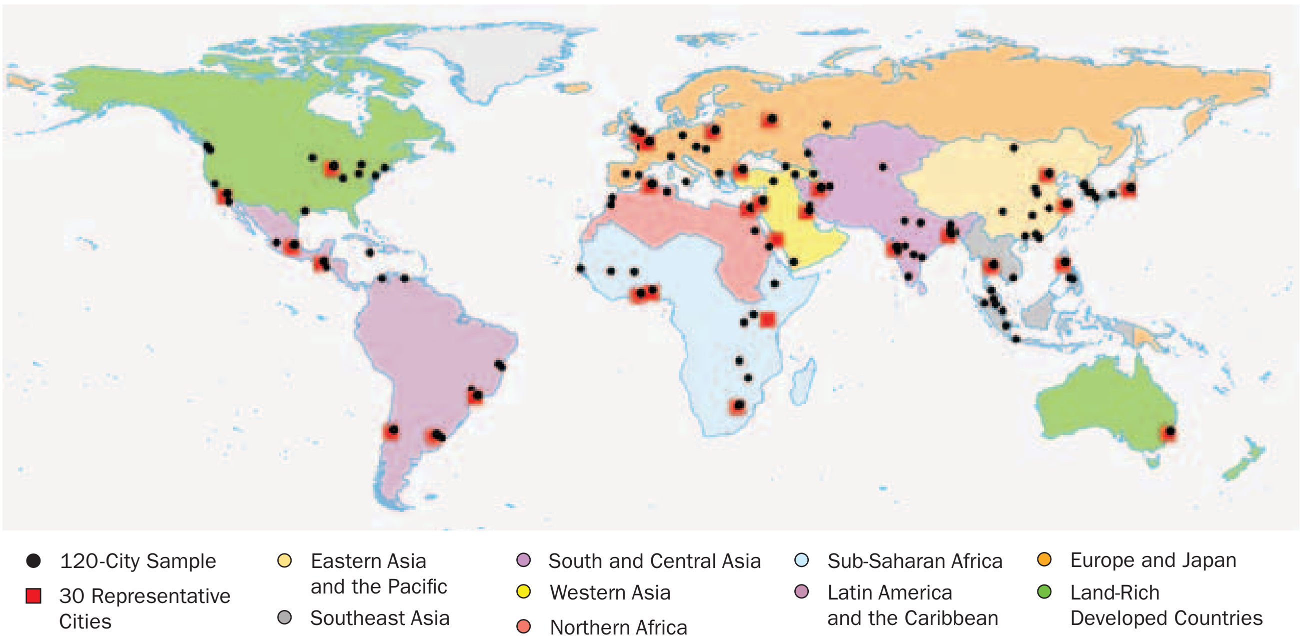
The global sample of 120 cities is a stratified sample from this universe including cities from nine geographic regions, four population size classes, and four per capita income classes. The nine-region classification approximates that of UN-HABITAT, except that we grouped the developed countries into two regions: land-rich developed countries that had more than 0.6 hectares of arable land per capita in 2000 (United States, Canada, and Australia); and other developed countries (Japan and Europe, including the Russian Federation) (figure 1.7).

For each sample city we obtained a medium-resolution Landsat satellite image for each time period. These images were classified into built-up and non-built-up 30×30 meter pixels, using a thematic extraction algorithm (Angel et al. 2005, chapter 3). Using 10,000 Google Earth validation sites, Potere et al. (2009) reported that pixels identified as built-up in our sample were found to be built-up in Google Earth 91 percent of the time and those identified as urban were identified in our sample 89 percent of the time, confirming a relatively high level of accuracy.

We also obtained population figures for two census periods (circa 1990 and 2000) for the administrative districts of each city encompassing its built-up area. We interpolated the population in these districts for the dates corresponding to the satellite images, assuming a constant rate of population growth between census periods. Using ArcGIS software, we then calculated the metrics described earlier (except for centrality) within the relevant administrative districts for all 120 cities in this global sample.

This data set allowed us to estimate and explain (1) variations in urban extent and in the rate of urban expansion; (2) variations in density and in the rate of density change; and (3) variations in fragmentation and in the rate of change in fragmentation during the 1990s. Variations in compactness in this sample are presented in *The Atlas of Urban Expansion* (Angel et al. 2010c) and are now being analyzed to determine, among other things, to what extent city footprints have been and are likely to remain roughly circular in shape.

FIGURE 1.7
Nine Regions, the Global Sample of 120 Cities, and the Representative Sample of 30 Cities



The Set of 20 U.S. Cities, 1910–2000

Historical population density data at the census tract level for U.S. cities and metropolitan areas is now readily available in digital maps that can be analyzed using ArcGIS software (National Historical Geographic Information System 2010). Seven of the 20 cities chosen for analysis have census tract digital maps and population data extending back to 1910; only three cities have maps for 1920 because of data loss; eleven additional cities have tract density maps from 1930 onwards, and the remaining two cities have maps from 1940 onwards.

This data set allowed us to estimate and explain six key factors: (1) long-term density change; (2) changes in the rate of density change over time; (3) changes in the tract density gradient; (4) changes in the rate of change of the gradient over time; (5) changes in the tract density intercept; and (6) changes in the rate of change of the intercept over time. To determine whether these findings in U.S. cities were applicable to the world at large, we needed a supplemental data set that would at least allow us to estimate and explain long-term urban expansion and density change in the universe of cities as a whole.

Representative Sample of 30 Global Cities, 1800–2000

A representative sample of 30 cities was created to explore long-term changes in urban population density from 1800 to 2000. The selection of cities for historical analysis was guided by three factors: their inclusion in the global sample of 120 cities; their regional distribution; and the availability of historic maps depicting their built-up area at 20 or 25 year intervals.

The selected maps depict the totality of the built-up area of the metropolitan agglomeration and contain sufficient reference points that could be identified on Google Earth so they could be stretched to fit a geographically accurate representation of space. This process, known as georeferencing, ensured that maps of different sizes and scales could be compared accurately to one another.

Arriving at an estimate of population density required population data in addi-

The old center of Paris, France, and its new suburban fringe

tion to built-up area data. Two publications proved invaluable to our investigation of historical urban populations (United Nations Population Division 2008; Chandler and Fox 1974). At earlier dates the correspondence between population figures and the urbanized area was clear, but for later dates it became more difficult to discern whether the reported population matched the extent of the urbanized area. For 1990 and 2000 we again had accurate data.

We created digitized maps of the built-up area for each city for each date, and the area of each built-up area map was calculated using ArcGIS software. The population associated with each map was interpolated from available historical population data, assuming a constant population growth rate in the intervening period. A total of 261 maps were used to calculate urban extent and average population densities and their change over time in the 30 cities in the sample—an average of 8.7 maps per city approximately 19 years apart—such as the historic map of Paris in 1834. This data set allowed us to estimate and explain long-term urban expansion and density change as well as the rate of density change over the decades on a global historical scale (figure 1.8).

The Universe of 3,646 Large Cities, 2000

We created a new global digital map on a Google Earth platform of the urban land cover of all large cities with populations of 100,000 or more in the year 2000, based on Mod500 satellite imagery (pixel size 463 × 463 meters). Potere and his colleagues (2009, 6553) tested the accuracy of eight global urban land cover maps and concluded: "Among the eight maps examined for accuracy, the Mod500 map was found to be the most accurate by all three accuracy measures employed."

This map allowed us to estimate and explain the extent of urban land cover and

The built-up area of Paris, France, 1834

FIGURE 1.8
The Expansion of Paris, France, 1800–2000

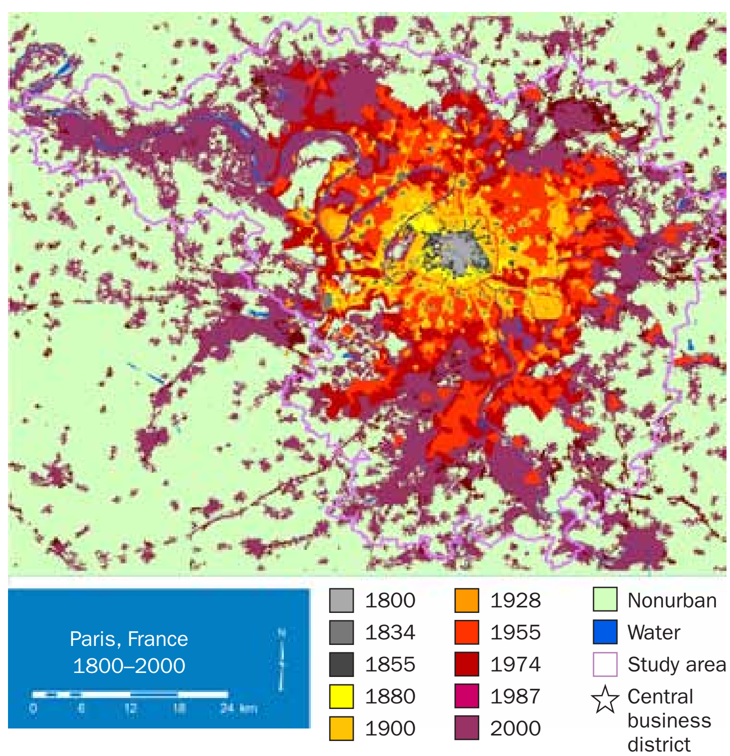
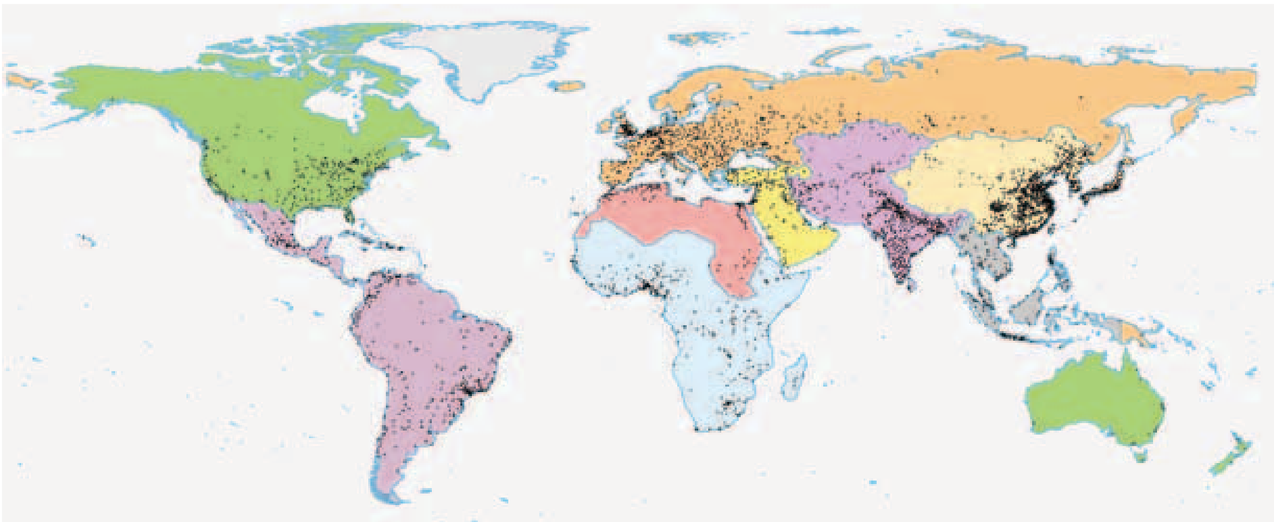


FIGURE 1.9
The Location of 3,646 Large Cities in Nine World Regions, 2000



- Eastern Asia and the Pacific
- Southeast Asia
- South and Central Asia
- Western Asia
- Northern Africa
- Sub-Saharan Africa
- Latin America and the Caribbean
- Europe and Japan
- Land-Rich Developed Countries

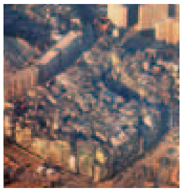
average built-up area densities in all large cities, countries, and world regions. Given realistic assumptions about long-term density change, it also made possible the projection of urban land cover for all countries for every decade between 2010 and 2050.

We refined the Mod500 map to include 311 new urban clusters for large cities that had no corresponding clusters in the Mod500 map, but we did not change the extent of any of Mod500 clusters (Angel et al. 2010e). As a result, we now have a map of urban clusters with a 463-square meter pixel size that are associated with a total of 3,646 named large cities and metropolitan areas in all regions (figure 1.9). These cities had a total population of 2.01 billion people in 2000 (Brinkhoff 2010). The population estimates are associated with the name of the city or metropolitan agglomeration, but are not populations within a well-defined administrative boundary.

SUMMARY

An urban planning strategy that can effectively meet the challenges posed by future worldwide urban expansion cannot rely on simply transplanting a containment strategy from one city, where it may be sensible and advisable, to another one, where it may not be, without a deeper understanding of the key spatial dimensions of these cities and their changes over time.

This policy focus report seeks to enrich our understanding of the context in which planning must take place in different cities around the world using empirical data on key parameters that characterize important elements of their spatial structure and their change over time. Carefully selected metrics and new data sets now allow us to construct a comprehensive and consistent global and historical perspective on urban expansion.



CHAPTER 2

The Persistent Decline in Urban Densities

Urban densities have been declining in cities around the world, in some cases for a century or more. This chapter presents evidence from our global and U.S. data sets to illustrate this trend and to highlight some important differences in average densities among cities in nine world regions.

DENSITY DIFFERENCES

Densities vary by a factor of 30 or more among the 120 cities in our global sample: Dhaka, the capital of Bangladesh, had the highest built-up area density in 2000 at 555 persons per hectare (p/ha), followed by Hong Kong at 530 p/ha. Tacoma, Washington, had the lowest density at 15.7 p/ha.

Average built-up area densities in cities in land-rich developed countries in the global sample were one-third those of cities in Europe and Japan, and the latter, in turn, were roughly half those of cities in developing countries. The average built-up area density in 2000 was 23 p/ha in 13 cities in land-rich developed countries; 67 p/ha in the 19 cities in Europe and Japan; and 136 p/ha in the 88 cities in developing countries. All of these averages were significantly different from each other.

Multiple regression models based on the classic economic theory of urban spatial structure could explain about 75 percent of the variation in average built-up area density among the 120 cities in the sample.

- Cities in countries with higher incomes—related to higher land consumption, extensive car ownership, and lower household sizes—had lower densities: A doubling of income per capita was associated with a 40 percent decline in average density.
- Large cities had significantly higher average densities than smaller cities: A doubling of the city population was associated with a 19 percent increase in density.
- Cities in countries with higher gasoline prices had higher densities: A doubling

Downtown Hong Kong, China

Downtown Tacoma, Washington

High-density populations in low-rise buildings, Dhaka, Bangladesh

of gasoline prices was associated with a 16 percent increase in density.

- Cities in countries with extensive arable lands (a proxy variable for agricultural land prices) had lower densities: A doubling of arable land per capita was associated with a 25 percent decline in average density.
- Cities with fewer geographical constraints on their expansion and cities in countries with higher levels of income inequality also had lower densities.

Built-up area densities for the global universe of 3,646 large cities (those with populations of 100,000 or more in 2000) were similar to those obtained for the sample of 120 cities, with a number of distinctions. First, because of the differences in pixel size between the Landsat-based maps used for the sample of 120 cities and the Mod500-based digital maps used for the universe, there are differences in the physical extent of cities between the two sets of maps, and the Mod500 maps may be less reliable in identifying the built-up areas of cities correctly. Second, some of the country-wide explanatory variables that proved to be significant in the statistical models in the sample (specifically, gasoline prices) were found to be not significant at the 95 percent level of confidence in the universe of large cities, possibly because of the large number of cities in certain countries.

That said, average built-up area densities in cities in land-rich developed countries in 2000 were still found to be roughly half those of cities in Europe and Japan, and the latter in turn were roughly half those of cities in developing countries. The average built-up area density in 2000 was 25 p/ha in cities in land-rich developed countries; 50p/ha in cities in Europe and Japan; and 129 p/ha in cities in developing countries. Again, all of these averages were significantly different from each other.

Multiple regression models based on the classic economic theory of urban spatial structure could explain more than 40 percent of the variation in average built-up area density among the 3,646 large cities in the universe.

- Cities in countries with higher incomes had lower densities: A doubling of income per capita was associated with a 25 percent decline in average density.

- Large cities had significantly higher average densities than smaller cities: A doubling of the city population was associated with a 16 percent increase in density.
- Cities in countries with extensive arable lands (a proxy variable for agricultural land prices) had lower densities: A doubling of arable land per capita was associated with a 27 percent decline in average density.

Figure 2.1 compares average built-up area densities in the global sample of 120 cities in 1990 and 2000 and in the universe of cities in 2000. A map of the average density in large cities in all 158 countries that had large cities in 2000 provides visual confirmation of the statistical results (figure 2.2).

FIGURE 2.1
Average Built-Up Area Densities in Three World Regions

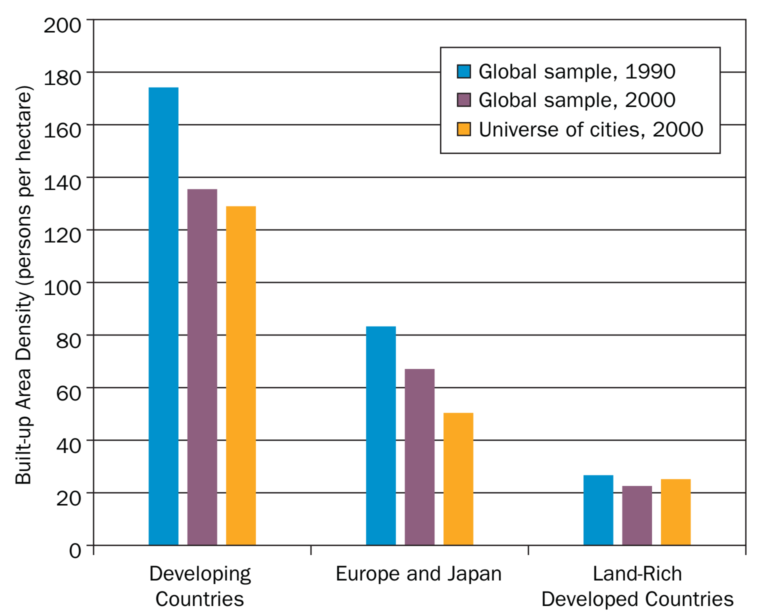
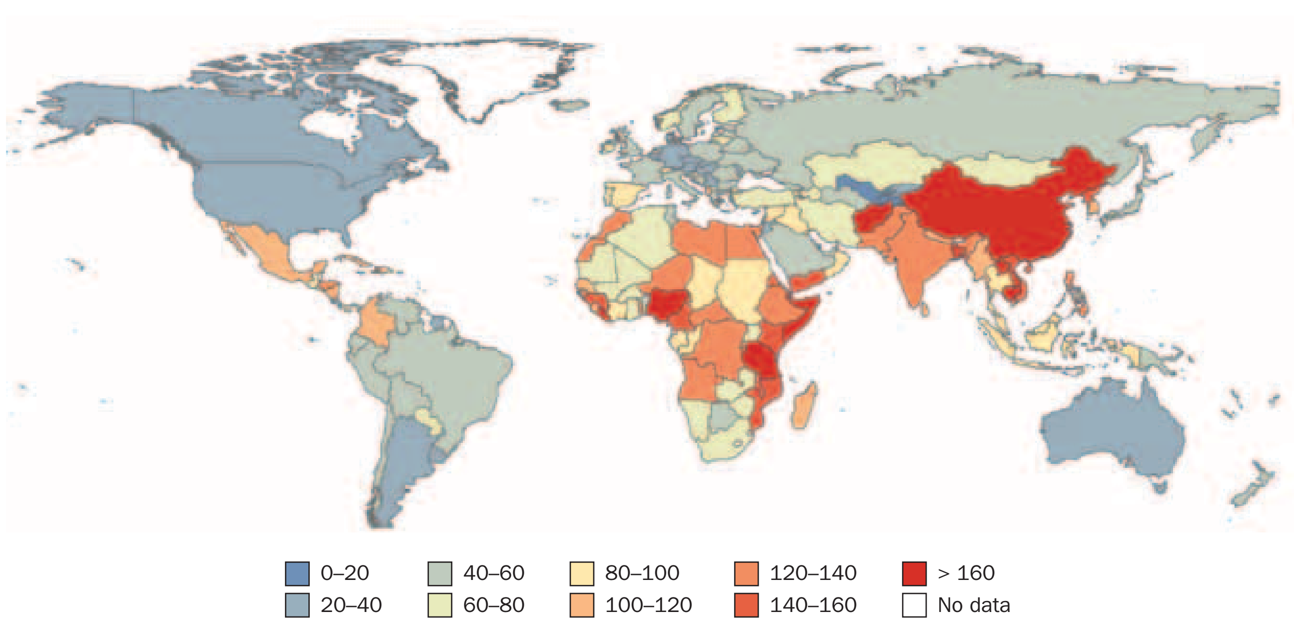


FIGURE 2.2
Average Density of Large Cities (in persons per hectare) in All Countries, 2000



DENSITY DECLINE

The decline in urban densities has been amply reported in the United States (Fulton et al. 2001) and, more recently, in Europe: "European cities were more compact and less sprawled in the 1950s than they are today, and urban sprawl is now a common phenomenon throughout Europe" (European Environment Agency 2006, 5) What has not been so evident is that this phenomenon is global in scope and includes cities in the developing countries as well.

The statistical evidence presented below contradicts the early claims of Berry, Simmons, and Tennant (1963, 401) that "non-Western cities experience increasing overcrowding, constant compactness, and a lower degree of expansion at the periphery than in the West." It also contradicts the more recent claims of Acioly (2000, 127) that "there was evidence that a general process of change was leading to more compact cities" in developing countries. Moreover, it contradicts the claims of Richardson, Bae, and Buxamusa (2000, 25) that cities in developing countries "are not becoming significantly less compact in spite of decelerating population growth and the beginnings of decentralization."

Density Decline in the Global Sample of 120 Cities, 1990–2000

Statistical analysis of the global sample of 120 cities between 1990 and 2000 shows that the average built-up area densities declined significantly, from a mean of 144

FIGURE 2.3
Density Decline in the Global Sample of 120 Cities, 1990–2000

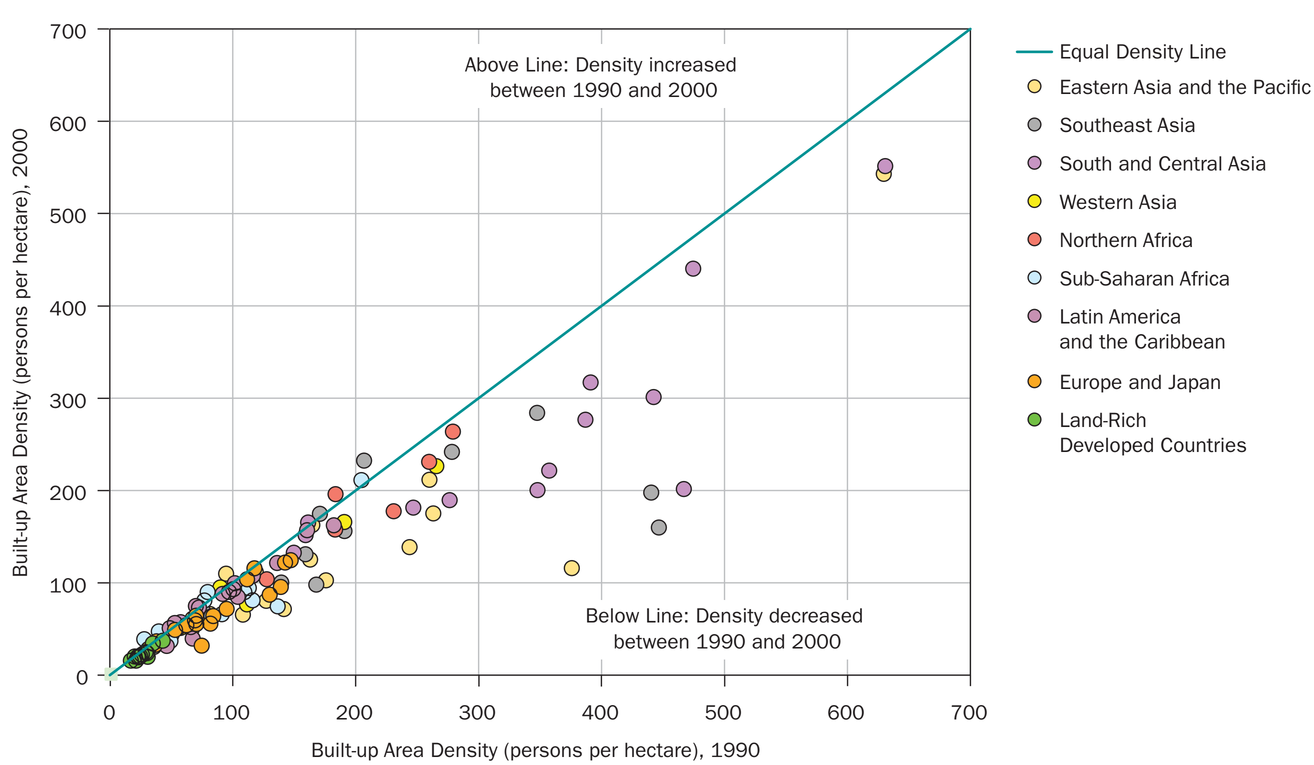
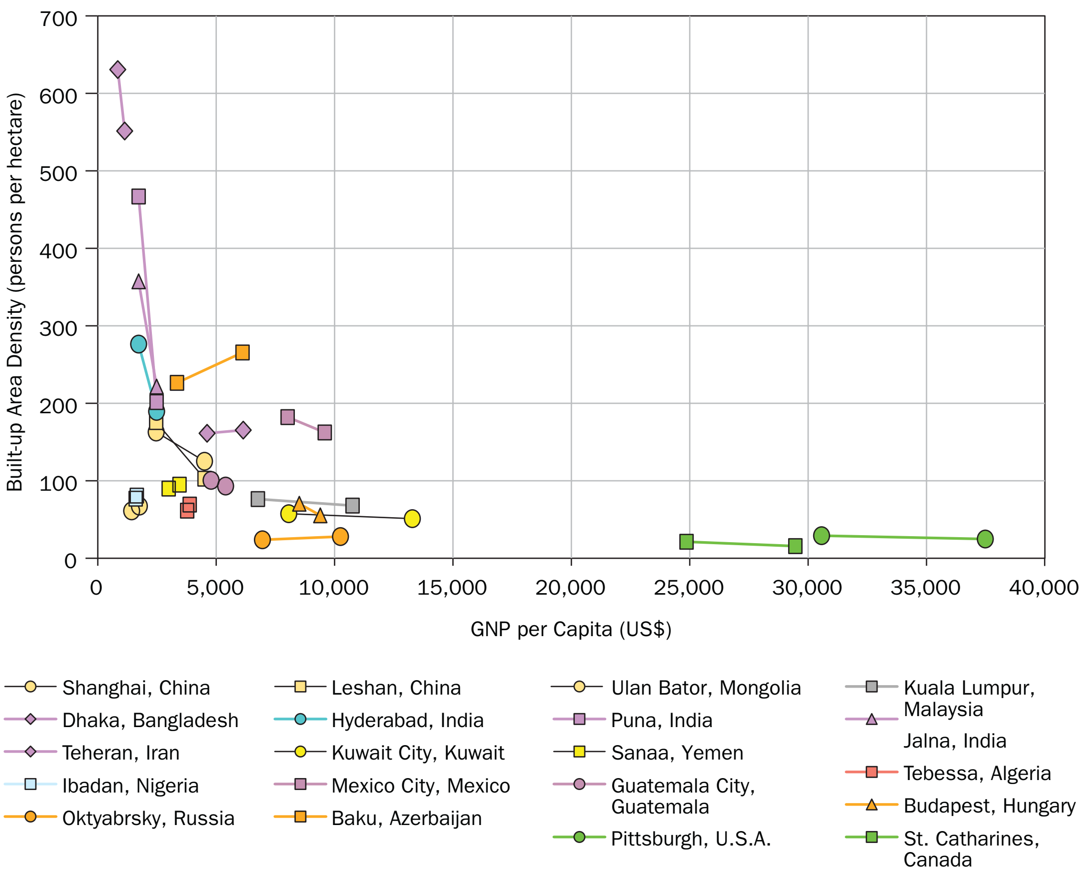


FIGURE 2.4

Density Change as a Function of Initial Density and Income Change In a Subsample of 20 Cities, 1990–2000



p/ha in 1990 to a mean of 112 p/ha in 2000. During that decade, average built-up area densities declined in 75 of the 88 cities in developing countries and in all 32 cities in developed countries (figure 2.3). There was no significant difference in the average rate of decline in built-up area densities in cities in the two groups and, on average, mean built-up area densities declined at an annual rate of 2.01 percent during this period.

The change in density between 1990 and 2000 as a function of income change and initial density is illustrated in figure 2.4 for 20 cities from the global sample.

Multiple regression models could explain 40 percent of the variation in the rates of density change in the global sample of 120 cities. Cities with rapidly growing populations had slower rates of density decline; cities in countries with rapidly growing incomes had faster rates of density decline; and cities with high initial densities had faster rates of density decline. Though these findings are robust, it is possible that the density decline observed in the global sample of cities between 1990 and 2000 was the result of particular conditions that prevailed during that decade.

Density Decline in 20 U.S. Cities, 1910–2000

To test the results from the decade of the 1990s over a longer time period, a separate analysis explored the change in densities of 20 U.S. cities from 1910 to 2000. The results show that average tract densities

FIGURE 2.5

The General Decline in Average Tract Densities in 20 U.S. Cities, 1910–2000

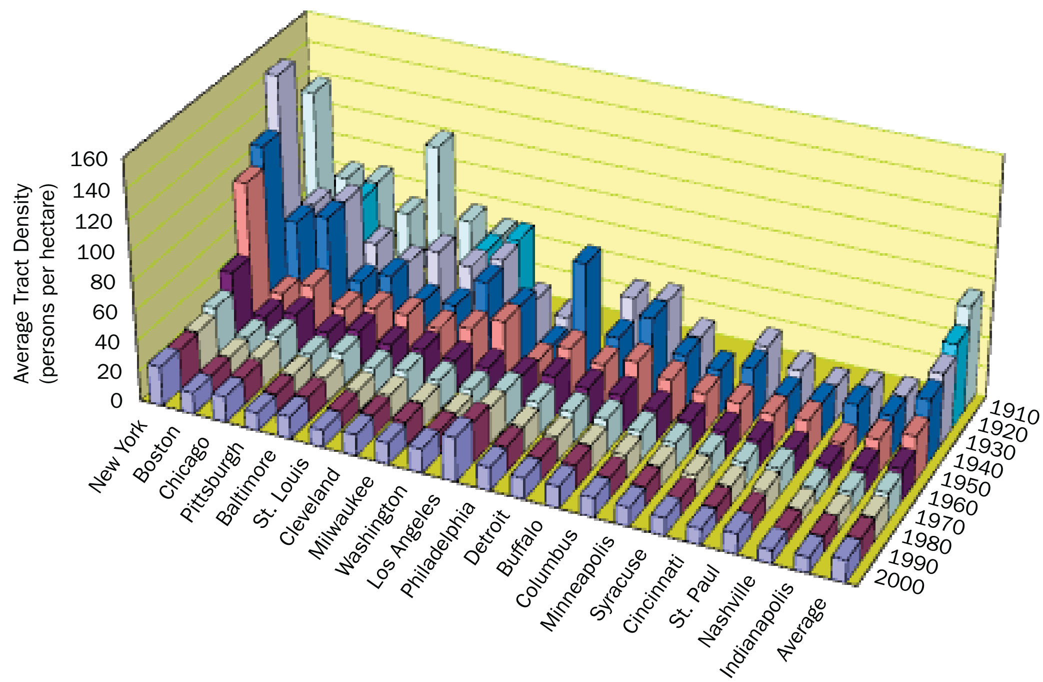
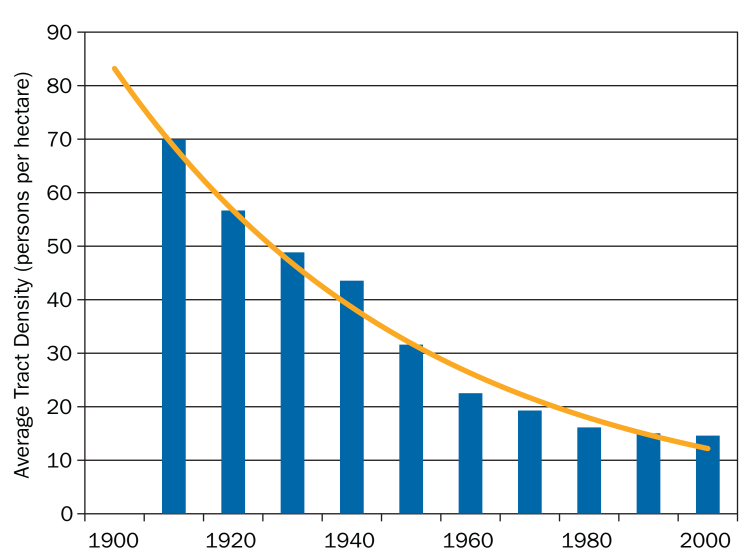


FIGURE 2.6

The Average Annual Rate of Decline in Tract Density in 20 U.S. Cities, 1910–2000



declined in 19 of the 20 cities (figure 2.5). The single exception was Los Angeles, where average tract density has increased since 1940, and by 2000 was the highest in the data set. A first-time modest increase in average tract density in the 1990s occurred in five other cities: New York, Washington, DC, St. Paul, Syracuse, and Nashville.

The average tract density declined in every decade since 1910, from 69.6 persons per hectare in 1910 to 14.6 persons per hectare in 2000, almost a five-fold decline (figure 2.5, far right row). Fitting an exponential curve to the average density in every decade from 1910 to 2000, we find that the average annual rate of decline for the entire period, assuming a constant rate, was 1.92 percent (figure 2.6).

Average tract density declines between any two consecutive census periods were registered in 124 out of the 153 observations, or 81 percent of the time. Subjecting these 153 individual observations to a single sample test we found that the average decline between census periods was signifi-cantly different from zero—it averaged 1.55 percent per annum.

Short-term rates of decline in average tract density, based on two data points ten years apart, appear to have peaked in the 1940s and 1950s, when they averaged 3 percent per annum; now they are on the decrease, averaging only 0.3 percent per annum in the 1990s (figure 2.7). Between 1990 and 2000, six cities registered an increase in average tract density: New York, Washington, DC, Los Angeles, St. Paul, Syracuse, and Nashville. Hence, while average densities in U.S. cities have been in general decline for almost a century, they may be reaching a plateau.

Figure 2.7 shows that the pattern of decline is the same for the 20 U.S. cities for which we have data from 1910 to 2000 and a larger set of 65 cities, which includes all

FIGURE 2.7
The Average Annual Rate of Tract Density Change in U.S. Cities, 1910–2000

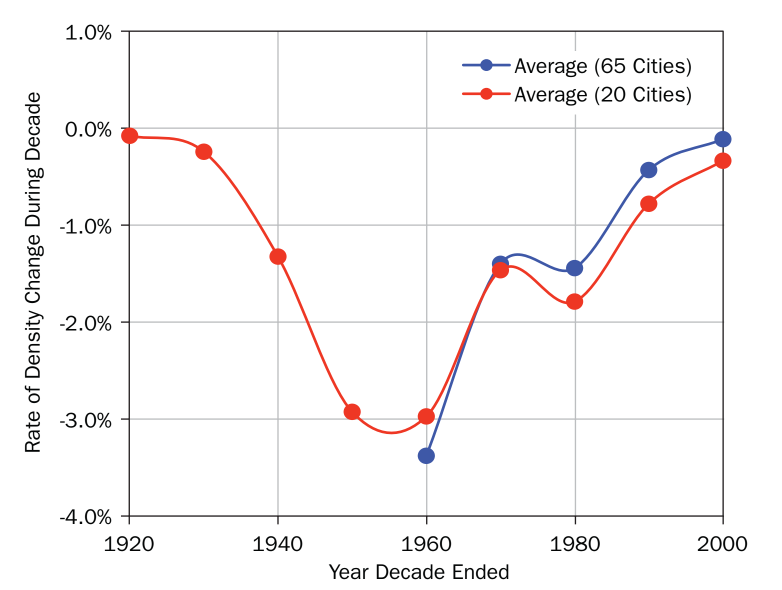
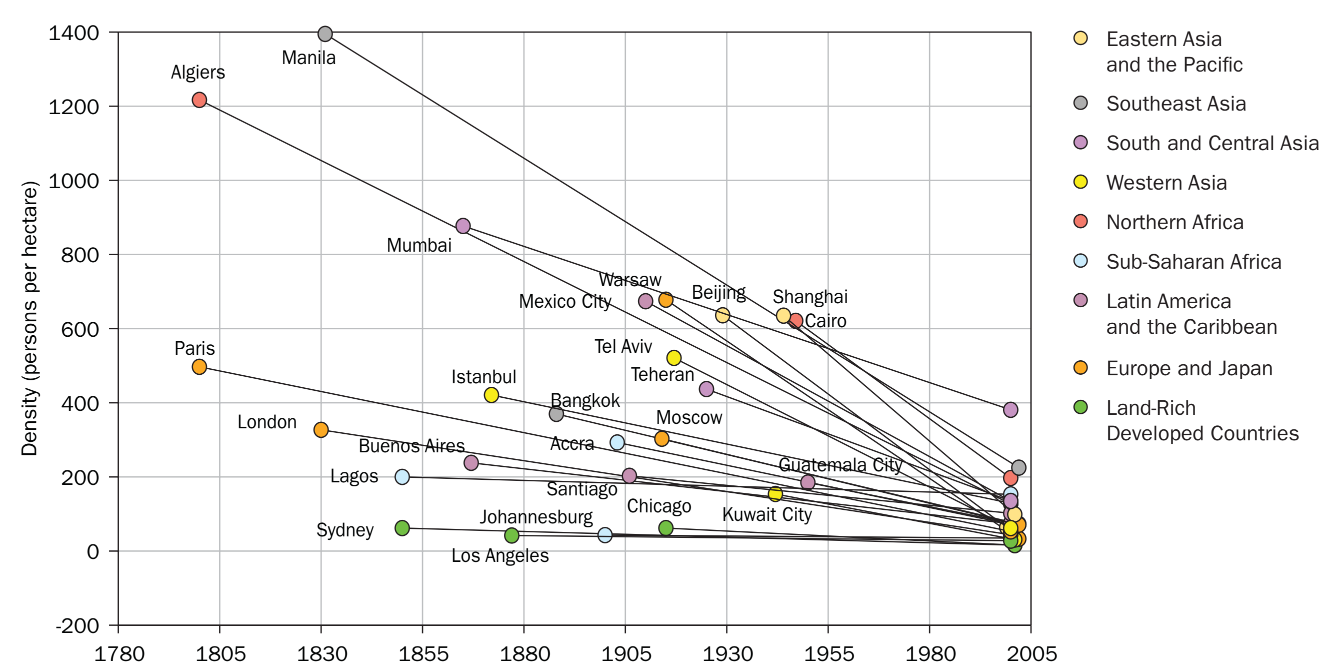


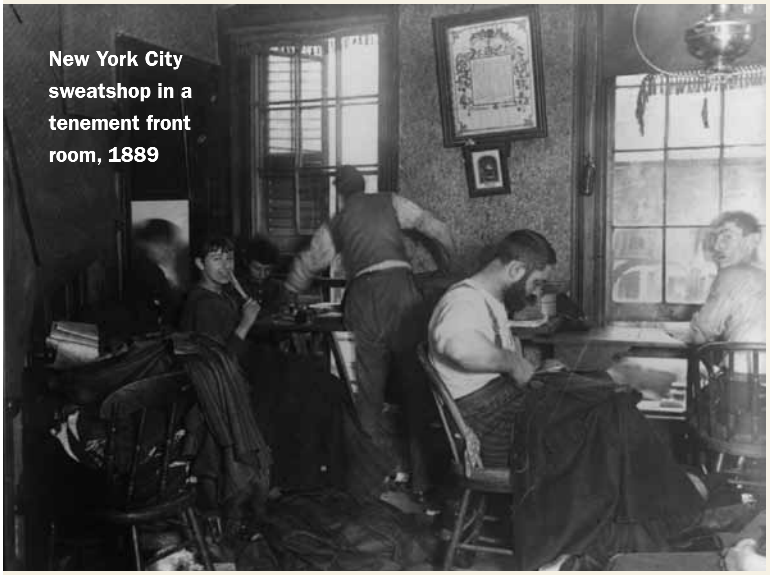
FIGURE 2.8
The General Decline in Built-Up Area Densities in 25 Representative Cities, 1800–2000



BOX 2.1
Density and Overcrowding

Proponents of densification tend to ignore the fact that in many cities urban population densities were (and still are) often too high, rather than too low, and needed to be reduced to ensure that people had adequate living space and to bring in more light and air into their residences. The tenements of New York City's Tenth Ward, for example, often contained 20 or more small apartments with no indoor plumbing on a 7.5x30 meter lot, each containing a household of 3 to 14 persons (Dolkart 2007). Such tenements were often used as a residence as well as a workplace (figure 2.9).

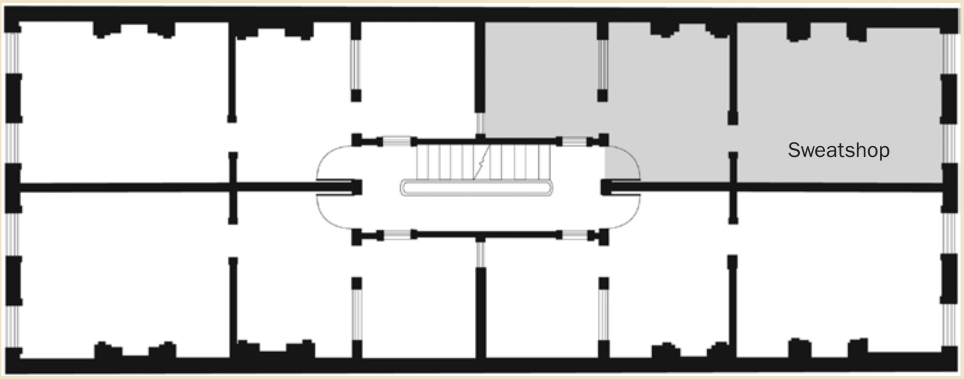
Politicians, reformers, and scholars were seriously concerned with living conditions in the city's crowded neighborhoods: "The Tenth Ward has a population at the rate of 185,513 to the square mile [708 p/ha]; the Seventeenth 170,006 [657 p/ha], and so on with others equally overcrowded. Portions of particular wards are even in worse condition" (*The New York Times* 1876).



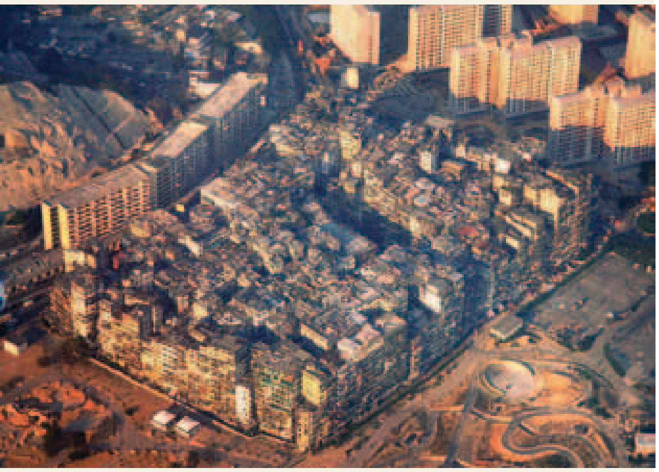
New York City sweatshop in a tenement front room, 1889

Suburbanization, as noted earlier, facilitated the decongestion of these neighborhoods: "The Lower East Side contained 398,000 people in 1910, 303,000 in 1920, 182,000 in 1930, and 147,000 in 1940. To reformers who had long pressed for the depopulation of the slums, this leveling out of neighborhoods was a welcome and much celebrated relief" (Jackson 1985, 185).

FIGURE 2.9
New York City Tenement Floor Plan, 1864



High densities were not unique to the industrial cities of the nineteenth century. The Kowloon Walled City in Hong Kong, demolished in 1992, boasted much higher densities than New York's Tenth Ward and virtually no light or air at all. At its peak in the mid-1980s it may have housed as many as 35,000 people on some 2.5 hectares, at an average density of 13,000 p/ha, making it the world's highest-density urban neighborhood ever documented (Liauw 2006).



Kowloon Walled City, Hong Kong, China (demolished in 1992)

The reduction of overcrowding in Chinese cities, through both suburbanization and redevelopment, has vastly increased floor space per person in recent decades. In Tianjin, for example, it increased from 6.5 m^2 in 1988 to 19.1 m^2 in 2000 and to 25.0 m^2 in 2005 (Tianjin Municipal Statistical Bureau 2006). It should be no surprise that this increase, coupled with the introduction of light and air into apartments, was accompanied by a corresponding decline in average densities.

U.S. metropolitan areas that had population in excess of 50,000 in 1950. The rate of decline began to slow rapidly during the 1950s, reversed itself in the 1960s, and then continued to decline from the 1970s onwards, indicating that average tract densities in U.S. cities have been in decline for almost a century.

Suburbanization, or the decline in centrality, was greatly accelerated by the advent of low-cost urban transport—omnibuses, horsecars, trolleys, commuter trains, and later buses and private automobiles—which made that density decline possible. Weber (1899, 475) noted long ago, "the 'rise of the suburbs' it is, which furnishes the solid basis of a hope that the evils of city life, so far as they result from overcrowding, may be in large part removed." The historical record contains numerous references to unacceptably high densities typically associated with overcrowding and unsanitary living conditions, and the urgent need to reduce them (box 2.1).

Density Decline in the Representative Sample of 30 Cities, 1800–2000

To examine whether this long-term trend in 20 U.S. cities is also evident in the world at large, we explored the change in built-up area density in a global sample of 30 cities over the past two centuries. Our analysis of the composite historical area maps for these cities allowed us to observe that, on the whole, they experienced both increasing and declining densities in the nineteenth century—before the emergence of inexpensive urban transport and the acceleration of economic development—and mostly declining densities in the twentieth century.

Urban densities peaked, on average, in 1894 (±15 years) and then began to decline. The most recent city in the sample to attain a density peak was Guatemala City in 1950 (figure 2.8). Densities declined fourfold from their peak, from an average of 430 p/ha to an average of 100 p/ha circa 2000, at an average annual rate of 1.5 percent. Density decline started in the last two decades of the nineteenth century, several decades before the advent of the automobile. By the end of the twentieth century, rates of density decline still averaged 1.0 percent per annum. At this rate, densities will decline by 26 percent in 30 years. At a rate of 1.5 percent per annum, they would decline by 36 percent in 30 years.

To test and explain differences in the historical annual rate of density change among cities in the global representative sample of 30 cities, we used multiple regression models with the annual rate of density change between two consecutive map dates as their dependent variable. The models explained 8 to 20 percent of the variation in the rate of change in urbanized area density between two consecutive dates. They showed that densities declined in the twentieth century, after many new forms of inexpensive transport were introduced.

Similar to the previous models of density change in the 1990s, they also showed that (1) rapid population growth resulted in slower density declines; (2) rapid income growth resulted in faster density declines; and (3) higher-density cities experienced more rapid density declines than lower-density cities.

DENSITY PROJECTIONS, 2000–2050

Based on these reported results, we project that future urban land cover in cities, countries, and regions the world over will take place under three density change scenarios:

- **High projection:** Assumes a 2 percent annual rate of density decline, corresponding to the average rate of decline in the global sample of 120 cities, 1990–2000.
- **Medium projection:** Assumes a 1 percent annual rate of density decline, corresponding to the short-term rate of density decline by the end of the twentieth century, as observed in the representative sample of 30 cities.

One of the last horsecars on rails, Bleecker Street, New York City, 1917

High-density urban expansion in Beijing, China

- **Low projection:** Assumes constant densities, or a 0 percent annual rate of density decline, corresponding to the observed rate of urban tract density decline in the 1990s in U.S. cities.

It may be argued that in the future effective policies will be found for increasing urban densities, resulting in reductions of the projected urban land cover. However, no such policies have been identified in any country at the present time. Very few cities in the world have densities that are increasing and, to the best of our knowledge, no city has long-term density increases as a result of conscious policies, including the strict containment regimes of London, Seoul, and Portland.

In some countries, such as China and India, the high projection may prove to be more appropriate, while in others, including the United States, the low projection may prove to be more realistic. Low projections may also be associated with increases in gasoline prices, as well as declining gas supplies, the increasing cost of gas production, or its increased taxation. If the models discussed earlier are correct, then the doubling of gasoline prices every decade may be sufficient to keep densities from declining.

The search for cost-effective and politically acceptable infrastructure strategies, regulations, and tax regimes that can lead to significant overall densification in low-density cities must continue in order to make them more sustainable. At the same time, appropriate strategies for managing urban expansion at sustainable densities in rapidly growing cities in developing countries must be identified and employed effectively. No matter how we choose to act, however, we should remain aware that conscious and conscientious efforts to make cities more dense will require the reversal of a very powerful and sustained global tendency for urban densities to decline.

CHAPTER 3
The Fragmentation of City Footprints

Expansion of informal settlements on the urban fringe of Quito, Ecuador, 2005

Cities and metropolitan areas the world over are now highly fragmented, and their fringes are disconnected patches of urban fabric broken up by swaths of vacant land. We are not only building cities at declining densities, but also creating urban environments that are fragmented and disconnected.

The fully built-out city of old, surrounded by a wall and situated in the open countryside, did not fragment any open space, nor was its built-up area fragmented by open space. The modern urban landscape is quite different. "Breaking out of the old bounds, walls, boulevards, or administrative limits which set it apart, the city has massively invaded the open country, though parts of the countryside may have kept their rural appearance" (Gottman and Harper 1990, 101). Both city and country now interpenetrate and fragment each other.

A key concern that has confronted urban planners and policy makers worldwide for some time is whether the fragmentation of the urban landscape is an inherent feature of contemporary cities that must be taken into account in planning for and managing urban expansion, or whether it is a disorderly, wasteful, and undesirable form of sprawl that must be brought under control through the employment of one type of containment strategy or another.

Sprawl was defined almost 50 years ago as "lack of continuity in expansion" (Clawson 1962, 99), and since then many writers have bemoaned the ill effects of scattered or leapfrogging development, and the costs it imposes on both the built environment and the rural fringe of cities. "[P]arcelization of farmlands leads to a checkerboard distribution of farmlands, i.e., many noncontiguous fields. Farming such scattered plots is problematic" (Pfeffer and Lapping 1995, 85).

Discontinuous development has been explained by economists as the result of the operation of market forces. Ewing (1994, 2), paraphrasing Lessinger (1962) and Ottensman (1977), explains: "Expectations of land appreciation on the urban fringe cause some landowners to withhold land from the market. . . The result is a discontinuous pattern of development."

Some economists have observed that while fragmentation may be inefficient in the short term, it leads to more efficient development patterns in the long term. "[C]ontrary to conventional wisdom, a freely functioning land market with discontinuous patterns of development inherently promotes higher density development" (Peiser 1989, 193). Such views suggest that fragmentation is indeed an inherent feature of the urban expansion process, not the result of the failure of land markets on the urban fringe, which would have to be addressed by ameliorative action on the part of the state.

While it would be difficult to dispute that some fragmentation on the urban fringe is necessary for the proper functioning of land markets and is indeed an inherent feature of the urban landscape, there is a quantitative aspect to this assertion that is left unexplored: How much fragmentation would be necessary and sufficient for the smooth functioning of the urban development process, and when can we determine that fragmentation is excessive and requires ameliorative action to reduce it?

We can ask other questions regarding fragmentation that require quantitative answers: How fragmented are cities and metropolitan areas, and what is the minimum observed level of fragmentation at the present time? Are cities becoming more or less fragmented over time? What level of fragmentation needs to be taken as a planning norm when projecting the area needed for urban expansion in a given city 20 to 30 years ahead?

More specific empirical questions can address levels of fragmentation in particular countries and cities: Are Chinese metropolitan areas, as some observers have suspected, more fragmented than other metropolitan areas (e.g., Webster et al. 2010)? Has urban containment in Portland, Oregon, reduced fragmentation within its urban growth boundary over time? Has it reduced it at a more rapid rate than, say, Houston, Texas, a city that does not practice any form of urban containment? These are all empirical questions that have not been properly addressed in the literature and that we examine here.

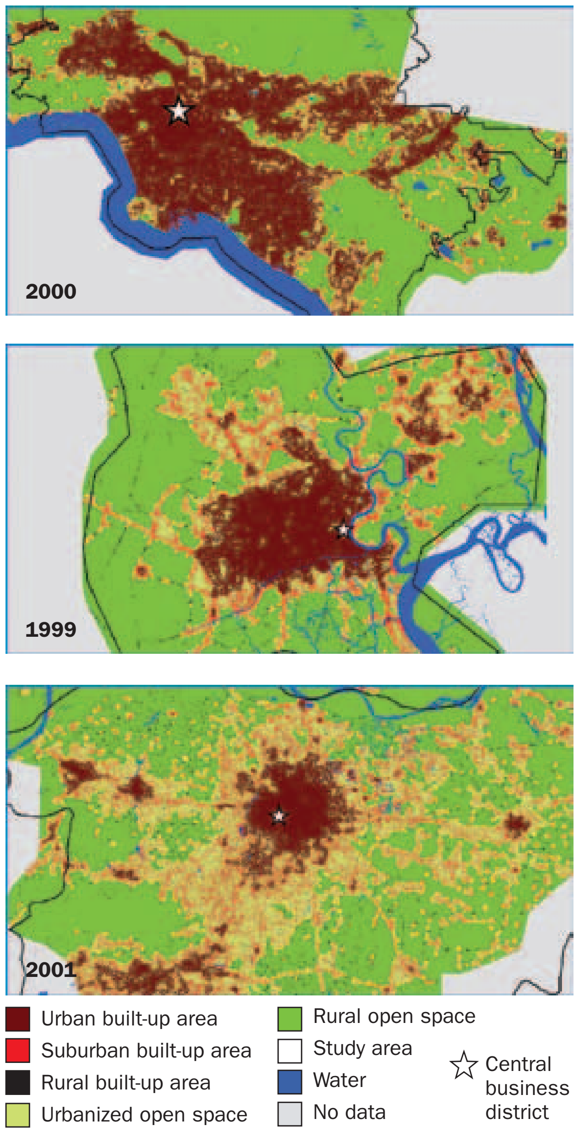
FRAGMENTATION IN THE GLOBAL SAMPLE OF CITIES, 1990–2000

Burchfield et al. (2006) follow Clawson (1962) in perceiving urban sprawl simply as the fragmentation of the urban landscape. They define fragmentation as the average share of an urban neighborhood that is occupied by open space. This definition does not distinguish between open space in permanent public or private use and open space that is vacant but will be built on eventually. The data required to distinguish public and private open spaces is rarely available, but anecdotal evidence suggests that permanently protected open space is a small fraction of the total amount of open space in and around the built-up areas of cities.

We measure fragmentation with two complementary metrics: the openness index and the city footprint ratio. The first, following Burchfield et al., measures the average share of open space pixels within a walking distance circle (1 km^2 in area) about every built-up pixel in the city. It is a neighborhood-scale measure of fragmentation. The second

FIGURE 3.1

The City Footprints of Los Angeles, California (2000), Ho Chi Minh City, Vietnam (1999), and Zhengzhou, China (2001)



is the ratio of the city footprint (that includes all the built-up or impervious surface area and all the urbanized open space in the city) and the built-up area. It is a citywide measure of fragmentation.

Both are area metrics, not per-person metrics, and are therefore independent of the density of built-up areas, making it possible to study density and fragmentation separately. The correlation between built-up area density and the city footprint ratio in 2000 in the global sample of 120 cities, for example, was negligible at -0.007.

Cities can be less sprawled in terms of built-up area density and more sprawled in terms of fragmentation at the same time. In 2000, Kolkata, India, ranked 7th in built-up area density in the global sample of 120 cities, but had the 6th highest city footprint ratio. In contrast, Los Angeles ranked 103rd in built-up area density while its city footprint ratio ranked 117th, one of the lowest in the sample.

What is the share of urbanized open space in a typical city footprint? Our key findings regarding fragmentation in the 1990s can be summarized as follows: The average value of the openness index in the global sample of 120 cities was almost one-half; that is, typical neighborhoods contained as much open space as built-up areas. Similarly, city footprints, on average, were double the built-up areas of cities; that is, on average, urbanized open spaces added an area to the city equivalent to its built-up area; at the lower range, open spaces added at least 36 percent to the built-up areas of cities.

More specifically, urbanized open space circa 2000 added, on average, 93 percent to the built-up areas of cities, ranging from only 40 percent in Los Angeles (the fourth lowest value), to nearly 90 percent in Ho Chi Minh City, Vietnam (the median value), and to 180 percent in Zhengzhou, China (the second highest value) (figure 3.1). Despite these considerable variations, cities around the world now typically contain urbanized open space equivalent in size to their built-up areas, a surprisingly high figure that is rarely referenced in the literature.

The mean value of the openness index for a typical city in the global sample was 0.47 in 1990 and 0.42 in 2000. These values were very similar to the values found for the United States by Burchfield et al. (2006, 602), who reported a value of 0.43 in 1976 and 0.42 in 1992. The openness index values appear to be normally distributed about their mean (figure 3.2). Two cities had values lower than 0.2 in 2000: São Paulo and Accra. Four cities had values in excess of 0.7 in 2000: Rajshahi and Saidpur in Bangladesh; Yulin in China; and Ilheus in Brazil.

Cities in developing countries had average values of 0.48 in 1990 and 0.43 in 2000. These values were significantly higher than those found in developed countries at 0.44 in 1990 and 0.39 in 2000. Cities in Europe and Japan had similar values to cities in land-rich developed countries.

The findings for the city footprint ratios paralleled those for the openness index with minor differences, but their distribution appears to be more skewed (figure 3.3). The mean value of the city footprint ratio for a typical city was 2.01 in 1990 and 1.93 in 2000, and there were no significant differences in this ratio between developing and developed countries or among the three regional groups. There were no values below 1.36 in both periods, no values below 1.4 in 1990, and only three values below 1.4 in 2000.

Given these results, we can begin to answer some of the questions posed earlier. On average, the inclusion of urbanized open space in the city footprint doubles the area of that footprint. If that average were to be considered a global norm, we would advise urban planners and policy makers not to be surprised to find half of their city's footprint occupied by urbanized open space, and that they should be surprised if it varied substantially from that norm.

In planning and preparing for urban expansion, policy makers may assume that in the absence of active intervention future city footprints can be expected to continue to be half empty as well. They should also be advised that, as a minimum global norm, they should expect urbanized open space to add no less than 40 percent to the built-up area of their city unless it was an atypical outlier. In other words, they may assume

FIGURE 3.2
The Frequency Distribution of the Openness Index for 120 Cities, 1990–2000

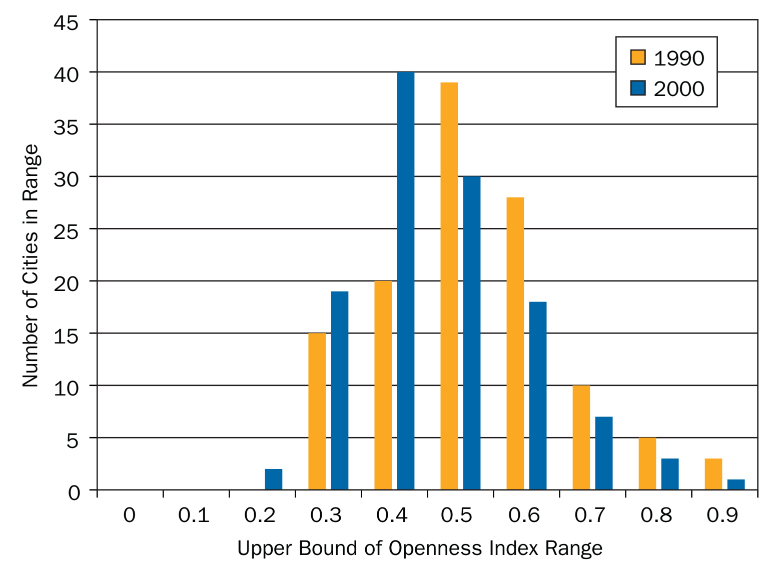
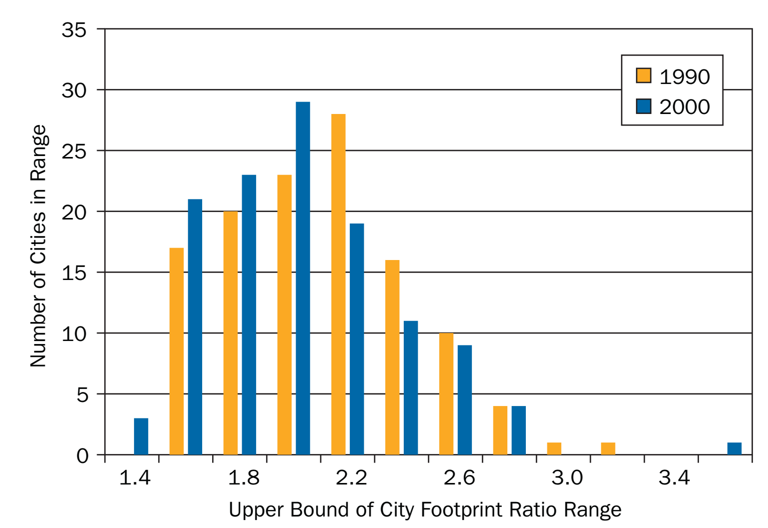


FIGURE 3.3
The Frequency Distribution of the City Footprint Ratio for 120 Cities, 1990–2000



that as some vacant spaces closer to the city center are filled in, new urbanized open space will be incorporated into the city footprint on the urban periphery, so that urbanized open space continues to add at least 40 percent to the built-up area of the city at any one time. Without additional information, we still cannot say whether this would be sufficient to ensure the smooth functioning of land markets.

Why are some cities more fragmented than others? Multiple regression models (based on the classic economic theory of urban spatial structure and its extensions introduced in chapter 1) could explain 30 to 50 percent of the variation in levels of fragmentation among cities in the global sample. The fragmentation of city footprints can be explained by variations in such factors as city population size, income, levels of car ownership, topographical restrictions on expansion, the availability of well water, the preponderance of informal settlements, and to a small extent by the presence of restrictions on expansion, as illustrated by the following findings.

- In 2000 large cities had significantly lower levels of fragmentation than smaller cities: A doubling of the city population was associated with an 11 percent decline in the openness index.
- Cities with more buildable land in and around them were more fragmented: A doubling of the share of buildable land was associated with a 12 percent increase in the openness index.
- Cities in countries with higher incomes also had higher levels of fragmentation: A doubling of income per capita was associated with a 12 percent increase in the openness index.
- That said, cities in countries with higher levels of car ownership per capita were less fragmented: A doubling of the level of car ownership per capita was associated with an 8 percent decline in the openness index.
- Access to well water also increased fragmentation, as already noted by Burchfield et al. (2006) in U.S. cities: A doubling of the share of the population that obtained its water from wells was associated with a 12 percent increase in the openness index.
- The density of built-up areas does not affect the spatial fragmentation of cities one way or another.
- The presence of informal settlements like those in Caracas was associated with a decline in fragmentation: A doubling of the share of the population in informal settlements was associated with an 8 percent decline in the openness index.
- The importance of agriculture to the country's economy was also associated with higher levels of fragmentation: A doubling of the share of the country's GDP from agriculture was associated with an 8 percent increase in the openness index.
- The availability of large quantities of agricultural lands in the country did not lead to the increased fragmentation of urban areas.
- Finally, planning restrictions were associated with a decline in fragmentation: A doubling of the area of the metropolitan plan where no development was allowed was associated with a 6 percent decline in the openness index.

COMPARATIVE CASE STUDIES

While it has been difficult to obtain comparative data to test the effects of policy on urban fragmentation at a global scale, it was possible to examine these effects in two case studies. The first one measures the decline in fragmentation in Portland, Oregon, a metropolitan area with a strict containment regime and compares it to the decline in fragmentation in Houston, Texas, a city

Informal settlements occupying marginal land with little or no fragmentation in Caracas, Venezuela, 2000

that has no containment regime. The second case study examines the effects of China's food security policies on the excessive fragmentation of Chinese cities in the global sample (excluding Hong Kong).

The Decline in Fragmentation in Portland and Houston

In 1973, the State of Oregon enacted Senate Bill 100 that mandated every urban area in the state, including Portland, to create an urban growth boundary. In 1979, a regional government, Metro, was created by Portland voters to manage the urban growth boundary in a three-county metropolitan area. Metro was charged with enforcing the boundary and extending it every five years to ensure a 20-year supply of residential land.

The chief aim of the boundary was to contain urban sprawl and preserve the natural beauty of the surrounding countryside. Sprawl was not defined precisely, but presumably it included both low-density development and fragmentation. After examining the change in built-up area density and in the city footprint ratio within the boundary between 1973 and 2005, we found that average built-up area density did not increase during this period, but rather decreased from 23.5 to 21.9 persons per hectare. By comparison, between 1990 and 2000, average built-up area density in Los Angeles declined from 35.0 to 34.3 p/ha and in Houston from 23.2 to 20.0 p/ha.

That said, the creation of Portland's urban growth boundary was associated with a rapid decline in fragmentation. Figure 3.4 shows the increase in the built-up area within Portland's urban growth boundary between 1973 and 2005. During this period, its city footprint ratio declined from 2.20 to 1.51 at an average rate of 1.2 percent per annum.

Houston's city footprints in 1990 and 2000 are shown in figure 3.5. Its city footprint ratio declined from 2.13 to 1.75 during this period, at an annual rate of 1.9 percent, whereas the city footprint ratio of Los Angeles declined from 1.47 to 1.40, at an annual rate of 0.5 percent. This is a surprising finding, considering that Houston, which does not have a zoning law let alone a containment policy, has a very open housing market and housing there is considerably more affordable than in Portland. In the third quarter of 2009, for example, it required 4.2 median household incomes to purchase a median-priced house in Portland and only 2.9 in Houston (Demographia 2010). Accelerated infill and the concomitant decline in overall fragmentation do occur naturally in open markets that are not subject to regulatory restrictions. We therefore urge caution in concluding that rigorous containment is a necessary policy tool for accelerating infill and reducing fragmentation.

FIGURE 3.4
The Decline in Fragmentation within Portland, Oregon's Urban Growth Boundary, 1973–2005

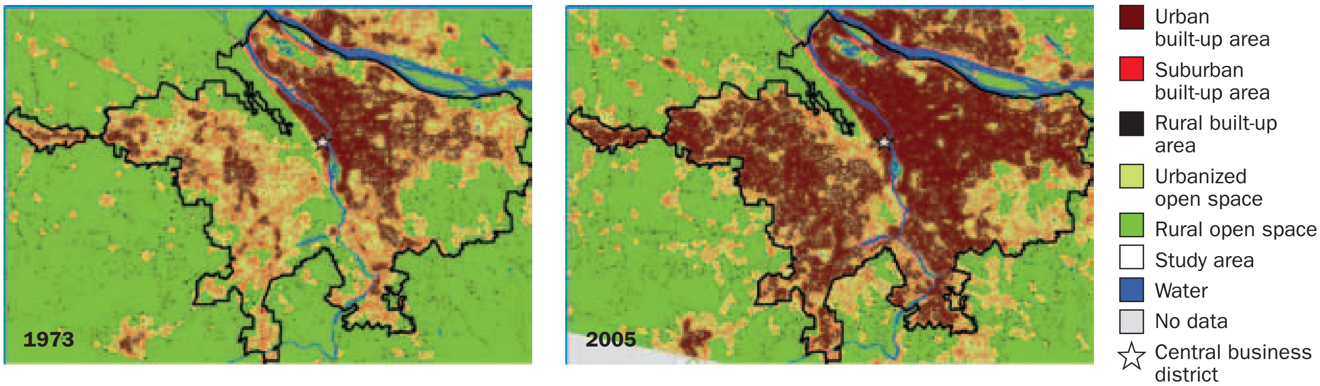
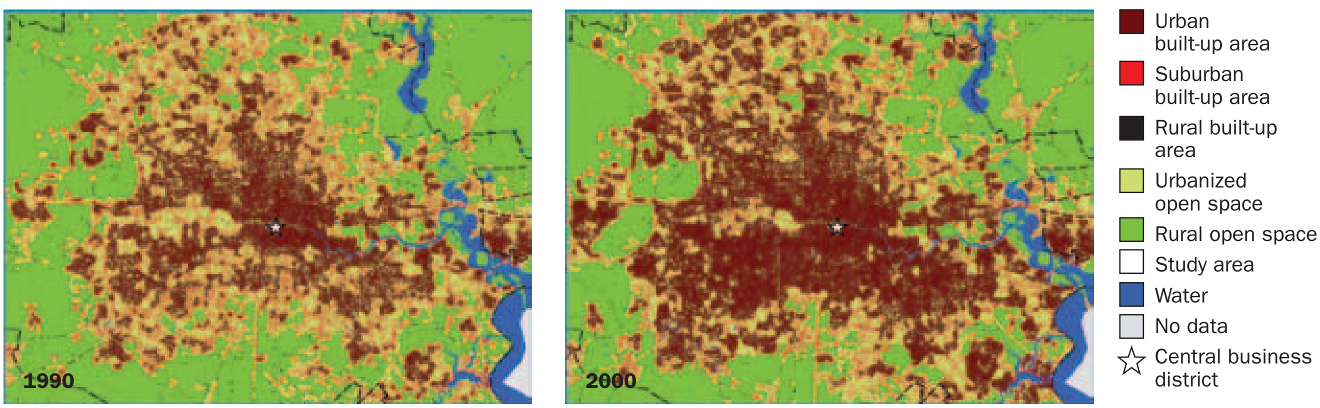


FIGURE 3.5
The Decline in Fragmentation in Houston, Texas, 1990–2000



Extensive Fragmentation in Chinese Cities

Although not well-documented, fragmentation in Chinese cities is extensive and significantly higher than in other countries. The mean value of the city footprint ratio was 2.40 for the nine Chinese cities (not including Hong Kong) in our global sample of 120 cities in the year 2000, ranging from 2.1 in Shanghai and Beijing to 2.8 in Zhengzhou. The ratio for the other cities in the sample was 1.89, and we can determine that the two values were significantly different at the 99 percent confidence level.

It has often been noted in the academic literature that there is a broad "rural-yet-urban" fringe in Chinese cities, a zone termed "desakota" by urban geographers in the early 1990s (Ginsburg 1990; McGee 1991). This zone has a dense pattern of villages with a high share of nonagricultural activities and a large number of workers who commute to urban jobs in the city proper. Chinese cities are often located on formerly densely settled agricultural lands. As they grow and expand outwards, they enclose and incorporate many villages, while distant villages become more urbanized in character. "The urbanization process unfolding is thus caused not only by a stream of rural-to-urban migrants but also by urbanization in place; that is, entire districts becoming more urbanized at all levels of the rural-urban continuum" (Guldin 1996, 278).

But, the existence of a dense pattern of urban villages on the periphery of Chinese cities does not explain the proliferation of cultivated lands within Chinese cities. Indeed, as Webster et al. (2010, 7) have noted, "[t]he result of sample land use surveys conducted in suburban areas in Chengdu, Tianjin, and Zhengzhou shows that on average about 34 percent of the land within existing ring roads remain under agricultural use while urban development expands much farther away from the city center."

Angel, Valdivia, and Lutzy (2011), following Webster et al., attributed this persistence of agriculture, much of it of a subsistence nature, to central government policies that limit the conversion of cultivated land to urban use in line with China's food security policies: "The Chinese government has given a high priority to agricultural land preservation in its food security policies, among them the Basic Farmland Protection Regulation of 1994, the 1998 Land Management Law, and the New Land Administration Act of 1999 [Lichtenberg and Ding 2007]" (Angel, Valdivia, and Lutzy 2011, 145).

Fragmented cultivated land in Zhengzhou, for example, is only half as productive as land in larger fields in the surrounding Henan Province, as most farming families have other sources of income (Angel, Valdivia, and Lutzy 2011). These authors also observed that strict central government limitations on land conversion may have forced the Municipality of Zhengzhou, for example, to appropriate the built-up areas of several of its surrounding villages while leaving their cultivated lands intact, to often demolish extensive affordable bedroom communities there, and to redevelop them for urban use.

Subsistence farming within the built-up area of Zhengzhou, China, 2007

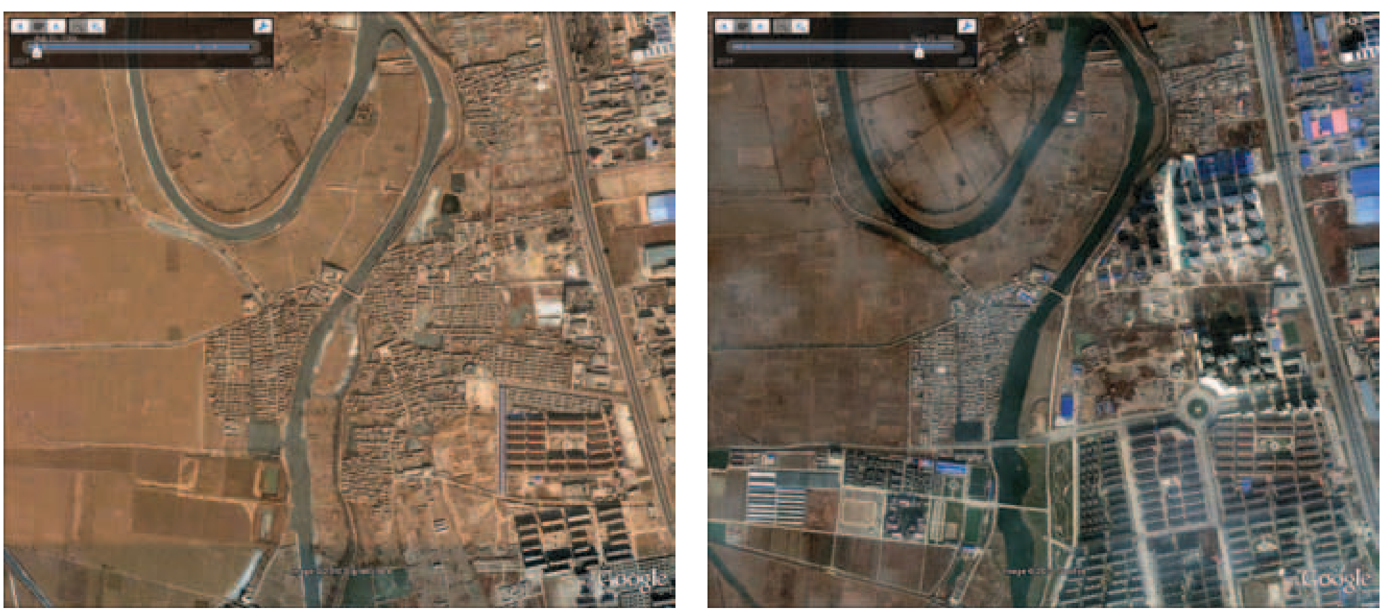
These policies exacerbate the fragmentation of Chinese cities, which results in inefficient infrastructure networks, longer commutes, urban land supply bottlenecks that make housing unaffordable, and unproductive agriculture (Angel, Valdivia, and Lutzy 2011). Furthermore, shying away from cultivated lands exacerbates forced evictions from—and demolitions of—rural structures. "China risks growing social instability and even violence if the government does not take effective action to address rising public anger about forced evictions and demolitions," according to a recent report released by the Chinese Urgent Action Working Group, a China-based rights lobby (Reuters 2010).

THE DECLINE IN FRAGMENTATION, 1990–2000

Levels of fragmentation measured by both the openness index and the city footprint ratio declined significantly between 1990 and 2000 in the global sample of 120 cities. More than two-thirds of these cities experienced a decline in the city footprint ratio, while fewer than one-third experienced an increase. On average, infill constituted 50.9 percent of all new development between the two periods, extension 26.0 percent, and leapfrog 23.1 percent.

The ten-year decline in the openness index between 1990 and 2000 was -0.05, representing a decline from 0.47 to 0.42. A parallel decline in the city footprint ratio amounted to -0.08, from 2.01 to 1.93. The rate of change of the openness index was -1.2 percent per year, and that of the city footprint ratio was -0.04 percent per year. Both rates were significantly different from zero and did not vary among the three regional groups or among developing and developed countries. To put the latter rate in perspective, it was one-third the rate of decline in the city footprint ratio within Portland's urban growth boundary between 1973 and 2005, which was 1.2 percent per annum.

Multiple regression models could explain 14 to 43 percent of the variation in the annual rate of change of the openness index in the 120 cities. There were parallel and



Dense affordable housing in urban villages demolished to make way for urban expansion while cultivated land remains vacant, Tianjin, China, 2004–2009

significant declines in both average built-up area densities and in levels of fragmentation during the 1990s. A 10 percent decline in density was associated with a 2.4 percent decline in fragmentation. In other words, the faster the rate of decline in built-up area density, the faster the rate of decline in the openness index.

This finding is important because it suggests that infill development does not necessarily increase the average built-up area density of the city as a whole. It is also interesting because a decline in density is typically associated with increased sprawl, while a decline in fragmentation is associated with decreased sprawl. In the decade of the 1990s, we found that sprawl measured as density decline had increased, while sprawl measured as fragmentation has decreased. It may be that low density and a high level of fragmentation are substitutes for different means of maintaining proximity to open space, which would explain why a decrease in density is associated with a decrease in fragmentation. On the other hand, this statistical relationship may be accidental and not causally related at all.

The models also show that the faster the rate of population growth in the city, the faster the rate of decline in the openness index. A 10 percent increase in the population growth rate is associated with a 2.7 percent decline in the rate of change in the index. Rapidly growing cities, in other words, resort to infill more readily than to scattered development. Rapid economic growth, in contrast to rapid population growth, leads to increased fragmentation. A 10 percent increase in the rate of growth of GDP per capita is associated with a 1 percent increase in the rate of growth of the openness index.

We also found that the higher the level of car ownership in the country, the faster the rate of decline in the openness index, but that effect, while significant, was minimal. Finally, the rate of inflation or the restrictions on the conversion of land from rural to urban use did not seem to affect significant changes in the rate of change of the index.

To conclude, the fragmentation of city footprints declined in the 1990s and cities therefore became less sprawled, if sprawl is looked at as scattered development. This finding stands in contrast to the evidence that built-up area density declined during the 1990s as well and cities became more sprawled, if sprawl is looked at as low-density development. That said, despite the decline in fragmentation observed in the 1990s, city footprints still contained urbanized open space that was roughly equal in area to the built-up area of cities.

FRAGMENTATION AND MAKING ROOM FOR URBAN EXPANSION

In what manner should the expected level of fragmentation of cities be taken into account when projecting and preparing the areas needed for urban expansion? While we cannot provide a definitive answer to this question, we do caution those making plans for urban expansion that not taking fragmentation into account may result in gross underestimation of areas needed for expansion later. The projected expansion area in a given city at a given future date is not simply the projected built-up area, but the projected city footprint.

The projected built-up area can be calculated as:

Projected Built-up Area =
Projected Population ÷
Projected Built-up Area Density

The projected city footprint must be calculated as:

Projected City Footprint =
Projected Built-up Area x
Projected City Footprint Ratio

Metro, the regional government responsible for administering Portland's urban growth boundary, is required to expand the boundary every five years to ensure a 20-year residential land supply within the boundary. It is not at all clear from the available documentation whether this 20-year supply includes all vacant land within the boundary or whether it assumes that a significant share of urbanized open space (on the order of at least 40 percent of the built-up area) is to remain vacant at all times. If it does not, as some observers suspect, there is a good reason to expect that land supply in Portland will be constrained with concomitant effects on housing affordability (Cox 2001).

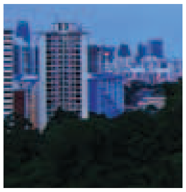
We have insufficient data to determine what range of ratios is common to cities with an unconstrained supply of urban land to ensure that housing remains affordable. However, we know that the city footprint ratio in Houston in 2000 was 1.8, and there were no constraints on land supply there. We also know that housing in Portland was and still is less affordable than housing in Houston. It stands to reason, therefore, that projected city footprint ratios in a city with unconstrained land supply should be higher than the minimum observed in the global sample of cities (1.4) and in Portland (1.5).

If this were the case, then the areas being planned for 20 to 30 years of urban expansion must be at least 50 percent larger than the areas obtained by simply projecting populations and built-up area densities. We cannot apply such an estimate to individual cities with different topographies (e.g., steep slopes or floodplains), different historical levels of density and fragmentation, and different amounts of open space in permanent use. Although we know that expected fragmentation levels are in global decline, we still urge planners to take fragmentation into account and to prepare substantially larger areas for expansion in the future.

SUMMARY

There may be sufficient cause for cities to employ rigorous containment measures to rein in excessive fragmentation where it is the result of misguided land policies. A case also can be made for reducing exurban fragmentation through policy intervention in areas that are expected to be outside city footprints projected 20 to 30 years into the future, for example by postponing the official designation of lands as urban or by delaying the extension of urban infrastructure networks into these exurban areas.

To prepare cities for expansion while ensuring the smooth functioning of land markets, we must be willing to designate ample room for 20 to 30 years of projected expansion—allowing for the expected level of fragmentation—and to make minimal preparations for rendering these areas of expansion accessible and supplying them with urban services. Such preparations, if done in earnest, cannot be considered rigorous containment.



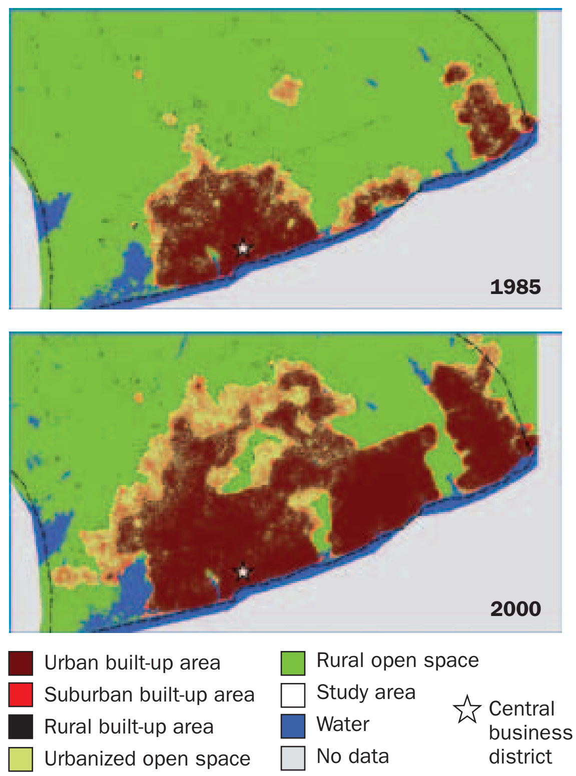
CHAPTER 4
The Dimensions of Global Urban Expansion, 2000–2050

The third attribute of urban expansion discussed in this report is the increase in urban land cover. Accra, the capital of Ghana, offers a startling example (figure 4.1). Between 1985 and 2000, the city's population grew from 1.8 to 2.7 million, a 50 percent increase, while its urban land cover expanded from 13,000 to 33,000 hectares, a 153 percent increase. Urban land cover in Accra grew more than twice as fast as its population.

We examined the growth rates of the urban population and the urban land cover in the global sample of 120 cities between 1990 and 2000. Population growth averaged 1.60 percent per annum, and land cover growth averaged 3.66 percent per annum. The difference between them was 2.06 percent. Thus, as in Accra, urban land cover in all 120 cities grew on average at more than double the growth rate of the urban population. At these rates, the world's urban population will double in 43 years and the world's urban land cover will double in only 19 years.

The rapid growth of urban land cover is by no means a recent phenomenon, as clearly shown in the historical expansion of Bangkok, the capital of Thailand, during the past 150 years (figure 4.2). Bangkok increased its urbanized area from 580 hectares in 1850 to 133,515 hectares in 2002. In 1944, for example, its urbanized area comprised 8,345 hectares, a 14-fold increase over its 1850 area. The city then doubled its area in 15 years (1944–1959), doubled it again in 9 years (1959–1968), doubled it again in 10 years (1968–1978), and doubled it yet again in 24 years (1978–2002). In other words, the urbanized area of Bangkok increased 16-fold between 1944 and 2002, at an average growth rate of 4.8 percent per annum.

FIGURE 4.1
Expansion of the Built-up Area of Accra, Ghana, 1985–2000

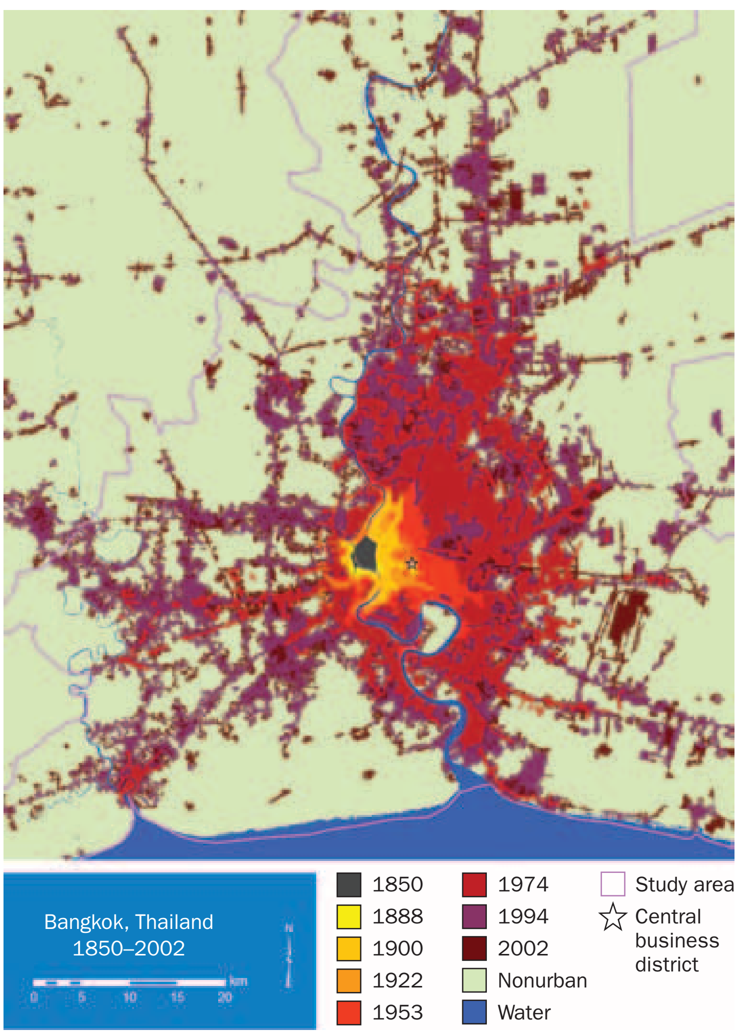


When we examined the growth rates of urban populations and their associated urban land covers in the representative global sample of 30 cities between 1800 and 2000, we found the rates in Bangkok were not atypical: 28 of the 30 cities studied increased their areas more than 16-fold during the twentieth century. The only exceptions were London and Paris, the two largest cities in the sample in 1900. These two cities had increased their areas 16-fold since 1874 and 1887 respectively.

On average, the 30 cities in the representative sample doubled their urbanized area in 16 years (1930–1946), doubled it again in 15 years (1946–1961), doubled it again in 15 years (1961–1976), and doubled it yet again in 23 years (1976–2000). Their urban land cover grew at an average long-term rate of 3.9 percent per annum.

The advocates of containment must come to terms with these facts. When and how could these cities have been contained? How could we contain a metropolitan area that expands up to 16 times its land area in 70 years?

FIGURE 4.2
The Expansion of Bangkok, Thailand, 1850–2002



The rapid growth in global urban land cover is likely to continue as long as urban populations continue to grow, incomes continue to rise, and urban transport remains relatively affordable. While considerable urban expansion may still occur in developed countries, most expansion in the coming decades will take place in the developing world. This report therefore seeks to refocus the attention of planners, policy makers, and concerned activists on urban expansion in developing countries and to examine the policy implications.

URBAN LAND COVER IN LARGE AND SMALL CITIES

We define large cities as those with populations of 100,000 or more circa 2000, and small cities as those with populations of less than 100,000. Large cities are to be distinguished from megacities—those few metropolitan areas across the globe that may contain 10 million people or more. In 2000 there were only 16 such areas in the world (United Nations Population Division 2008, file 11a), compared to 3,646 large cities.

These large cities contained some two billion people in the year 2000 and occupied a land area of 340,000 km^2 (table 4.1). Seventy percent of these cities were in developing countries, but they occupied less than one-half of the total land cover of all large cities.

Large cities worldwide accounted for 71 percent of the urban population. We should expect the respective shares of the urban population in small and large cities in all regions to be quite similar, but this is apparently not the case. This quandary is left for further investigation by other researchers.

The Mod500 global land cover map used to evaluate large cities could not be relied upon for calculating urban land cover in smaller cities and towns not easily distinguished from villages. To estimate total urban

TABLE 4.1

Regional Data on the Number, Population, and Land Cover of Large Cities, 2000

Region	Number of Cities	Total Population (millions)	Share of Urban Population (percent)	Total Land Cover (km^2)
Eastern Asia & the Pacific	891	458.1	89.2	42,218
Southeast Asia	196	107.3	52.2	12,883
South & Central Asia	539	287.0	65.9	29,705
Western Asia	157	89.6	73.6	12,999
Northern Africa	115	53.1	61.1	5,342
Sub-Saharan Africa	256	131.6	63.4	12,778
Latin America & the Caribbean	403	258.9	66.3	43,280
Europe & Japan	799	400.9	66.5	85,871
Land-Rich Developed Countries	293	226.9	84.8	94,759
All Developing Countries	2,557	1,385.5	70.7	159,206
All Developed Countries	1,092	627.8	72.1	180,630
World Total	3,646	2,013.3	71.1	339,836

land cover in small cities in each country, we first computed the total urban population in small cities and towns as the difference between the country's total urban population (United Nations Population Division 2008) and our calculated total population of large cities, both in the year 2000. The reader should note that because these estimates come from different data sources, subtracting them from one another can be problematic.

In our multiple regression models of the urban land cover of large cities, we found that a doubling of city population was associated with a 16.0 percent increase in density, and we used this density-population factor

Recent urban expansion in South Africa

in generating our estimates. The density metric of interest in estimating urban land cover is overall density, defined as the ratio of the total urban population to total urban land cover in a given area.

Total urban land cover in small cities was then calculated as the ratio of the total population to the overall density in small cities. We estimated the overall density in small cities in every region from information on the overall density in large cities, the median city population in large cities, the median city population in small cities, and the density-population factor introduced earlier.

According to our calculations, overall densities in small cities are roughly half those in large cities, and urban land cover in small cities added 266,039 km^2 to total global urban land cover in the year 2000.

URBAN LAND COVER IN ALL COUNTRIES, 2000

We combined our estimates of urban land cover in large and small cities to calculate the total in all countries and world regions in the year 2000 (Angel et al. 2010c, table 3), and these findings are summarized in table 4.2.

Worldwide, urban land cover occupied 0.47 percent of the total land area of countries, ranging from 0.62 percent in all developed countries to only 0.37 percent in developing countries. For example, urban areas occupied 0.85 percent of the land area in the countries of Southeast Asia, but only 0.12 percent in the countries of Sub-Saharan Africa. Urban land cover amounted to almost 4 percent of the total arable land area in the world as a whole, ranging from 1.5 percent of the arable land area in Sub-Saharan Africa to more than 5.6 percent in Latin America and the Caribbean and in Europe and Japan.

Among the 20 countries with the largest areas of urban land cover, five of them—United States, China, the Russian Federation, Brazil, and India—had more than 25,000 km^2 of urban land cover in the year 2000 (figure 4.3). The United States contained

TABLE 4.2
Estimated Urban Land Cover in All Regions, 2000

Region	Total Urban Population (Millions)	Urban Land Cover in Large Cities (km^2)	Urban Land Cover in Small cities (km^2)	Total Urban Land Cover (km^2)	Urban Land Cover as Percent of Total Land Area	Urban Land Cover as Percent of Total Arable Land
Eastern Asia & the Pacific	514	42,218	10,760	52,978	0.45	3.39
Southeast Asia	206	12,883	21,565	34,448	0.85	3.64
South & Central Asia	435	29,705	30,166	59,872	0.58	2.30
Western Asia	121	12,999	9,714	22,714	0.49	4.68
Northern Africa	87	5,342	6,775	12,104	0.15	2.69
Sub-Saharan Africa	208	12,778	13,721	26,500	0.12	1.54
Latin America & the Caribbean	390	43,280	47,952	91,233	0.45	5.63
Europe & Japan	602	85,871	88,755	174,581	0.76	5.62
Land-Rich Developed Countries	268	94,759	36,688	131,447	0.50	4.63
All Developing Countries	1,960	159,206	140,655	299,847	0.37	3.20
All Developed Countries	870	180,630	125,444	306,028	0.62	5.14
World Total	2,830	339,836	266,099	605,875	0.47	3.95

112,220 km² of urban land cover, or 18.5 percent of the global total, and more than double the 47,169 km² in urban land cover in the next highest country, China.

Figure 4.4 shows urban land cover as a share of the total land area of countries that had large cities in 2000.

- 12 countries had more than 8 percent of their land occupied by cities, among them Singapore, Belgium, and the Netherlands;
- 19 countries had 4 to 8 percent, among them the United Kingdom, Italy, Germany, and Japan.
- 26 countries had 2 to 4 percent, among them the Republic of Korea, France, Poland, Ukraine, and the Philippines.
- 31 additional countries had between 1 and 2 percent, among them the United States, Bangladesh, Turkey, and India.
- 34 more countries had between 0.5 and 1 percent, among them Indonesia, Pakistan, Venezuela, and China.

FIGURE 4.3

Twenty Countries with the Largest Areas of Urban Land Cover, 2000

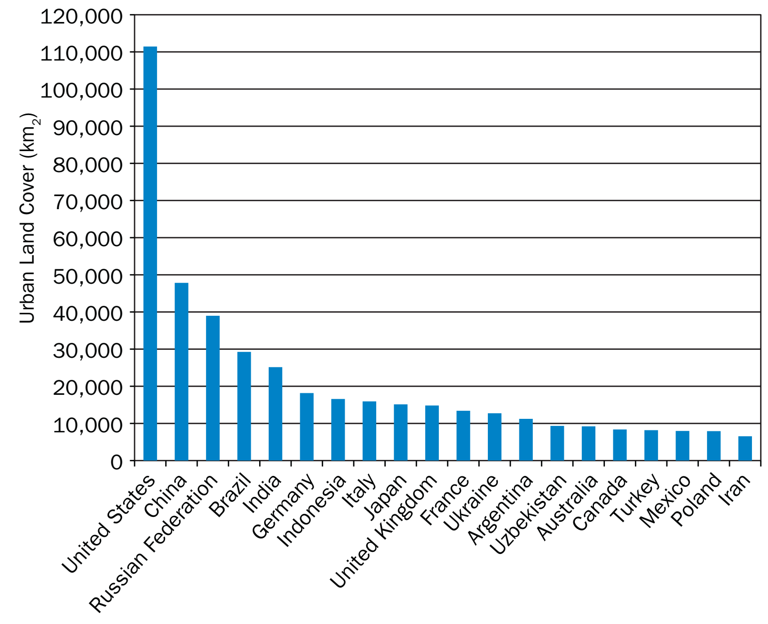
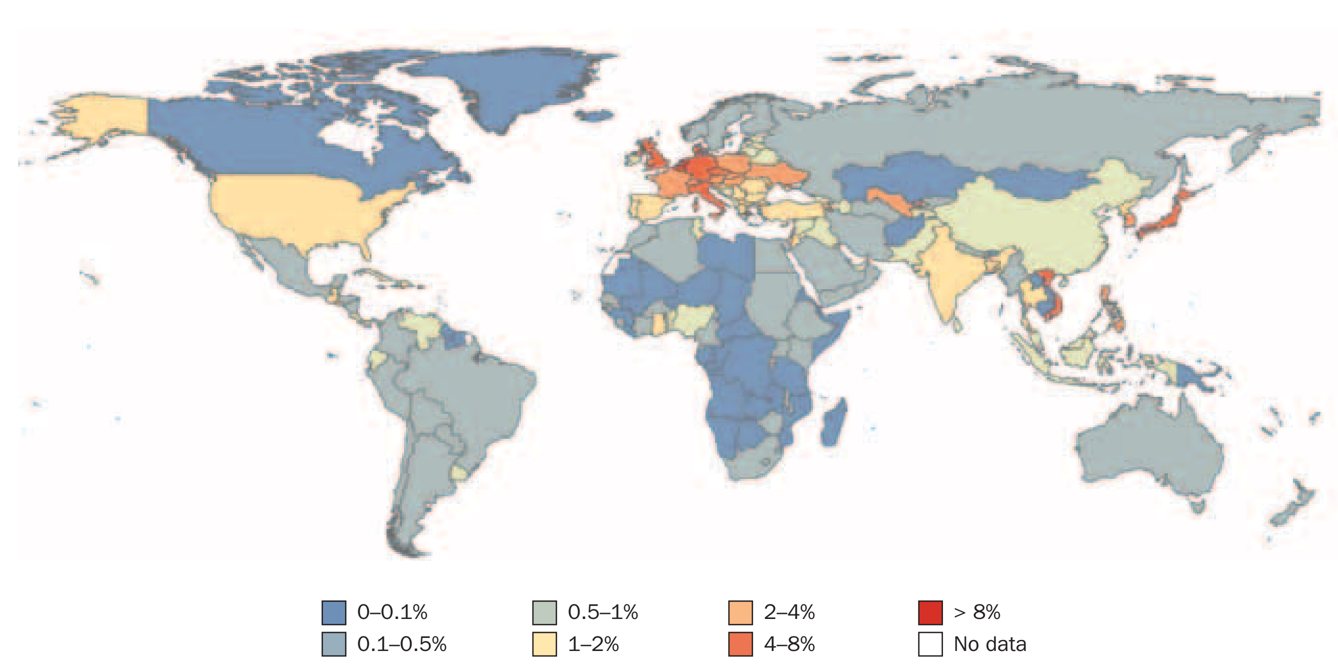


FIGURE 4.4

Urban Land Cover as a Share of Total Land Area in All Countries, 2000

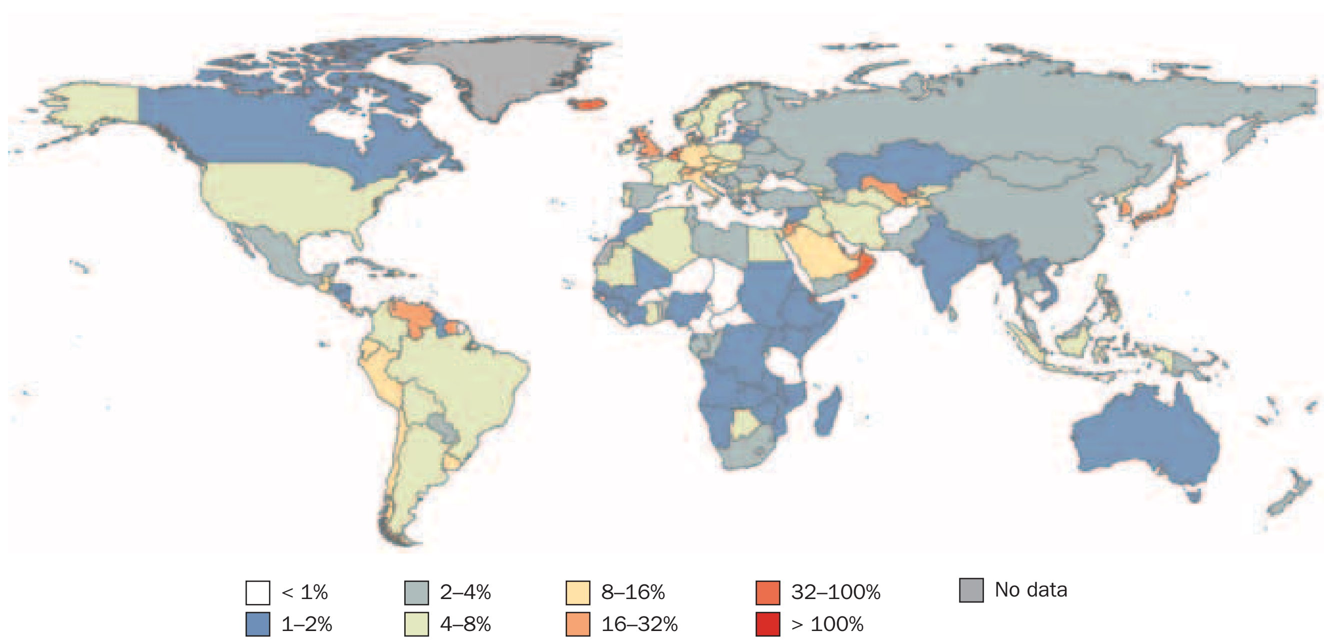


- 51 countries had between 0.1 and 0.5 percent, among them Brazil, Mexico, and Egypt.
- The remaining countries had less than 0.1 percent of their land in urban use, among them Canada, the Democratic Republic of Congo, and Mongolia.

Figure 4.5 shows urban land cover as a share of arable land in all countries that had large cities in 2000.

- 11 countries had more land in urban use than arable land, among them Singapore, Bahrain, Kuwait, Djibouti, and Qatar.
- 10 countries had urban land cover equivalent to 32–100 percent of arable land cover, among them Iceland, Belgium, and the Netherlands.
- In 18 countries it was equivalent to 16–32 percent of arable land cover, among them Japan, the United Kingdom, and the Republic of Korea.
- In 25 more countries it was equivalent to 8–16 percent of arable land cover, among them Germany, Italy, and Peru.
- In 38 additional countries it comprised 4–8 percent of arable land cover, among them Egypt, France, the United States, Brazil, and Poland.
- In 38 more countries it comprised 2–4 percent of arable land cover, among them China, Mexico, Spain, and the Russian Federation.
- In 40 more countries it comprised 1–2 percent of arable land cover, among them India, Bangladesh, Canada, Vietnam, and Ethiopia.
- The remaining countries had urban land cover that comprised less than 1 percent of arable land cover, among them Tanzania, Afghanistan, and Sudan.

FIGURE 4.5
Urban Land Cover as a Share of Arable Land in All Countries, 2000



EXPLAINING THE VARIATIONS IN URBAN LAND COVER

Multiple regression models were able to explain 93 to 95 percent of the variations in urban land cover among countries.

- A 10 percent increase in the urban population is associated with a 9.3 percent increase in urban land cover.
- A 10 percent increase in GNP per capita is associated with a 1.8 percent increase in urban land cover.
- A 10 percent increase in arable land per capita is associated with a 2.0 percent increase in urban land cover.
- A 10 percent increase in gasoline prices is associated with a 2.5 percent decrease in urban land cover.
- A 10 percent increase in informal settlements is associated with a 0.08 percent decrease in urban land cover.

In a second set of models, we obtained similar results using the total land area in large cities in each country in the year 2000 as the dependent variable. In a third set of models, we used the urban land cover in individual cities in the year 2000 as the dependent variable. These models were able to explain almost 70 percent of the variations in urban land cover in the universe of 3,646 large cities. City population, GNP per capita, and arable land were found to have similar effects on urban land cover in individual cities as those identified for countries. However, the coefficient for gasoline prices was not significantly different from 0 at the 95 percent confidence level.

In summary, the statistical models were found to be robust and were able to explain a very large amount of the variation in urban land cover among cities and countries. Variations in climate, cultural traditions, or the policy environment in different countries may matter less than the fundamental forces giving shape to the spatial extent of cities: population, income, low-cost peripheral land, and inexpensive transport.

PROJECTING URBAN LAND COVER IN ALL COUNTRIES, 2000–2050

We use three realistic density scenarios to project urban land cover into the future: (1) a high projection, assuming a projected density decline of 2 percent per annum; (2) a medium projection, assuming a projected density decline of 1 percent per annum; and (3) a low projection, assuming that densities remain unchanged.

Projected urban expansion between 2000 and 2050 will be mainly a function of urban population growth and density change, assuming that levels of fragmentation do not decline substantially during the coming decades. The land cover estimates used in our projections were obtained from our Mod500 global map of large cities, which has a 463-meter pixel resolution. These larger pixels contain significant amounts of urbanized open space. For the global sample of 120 cities, the built-up area calculated from the Landsat 30-meter pixel imagery was 0.71 the Mod500 urban land cover ($R^2 = 0.97$), and the city footprint was 1.16 the Mod500 urban land cover ($R^2 = 0.92$). The Mod500 estimates are therefore not unrealistic estimates of the land needed to accommodate the projected fragmentation in city footprints.

Table 4.3 summarizes the main characteristics of the projected growth in urban populations in different world regions, based on the latest UN projection (United Nations Population Division 2008).

- The world urban population is expected to increase from 3 billion in 2000 to 5 billion in 2030 and to 6.4 billion in 2050.
- The rate of increase of the world urban population is expected to slow down from 2 percent per annum in 2000 to 1.65 in 2030 and to 1.14 percent in 2050.

- The urban population in developing countries will grow at a rate five times faster than the urban population in developed countries.
- The urban population of the developed countries will stabilize at around 1 billion people.
- Almost all the growth in the world urban population will take place in developing countries. It will increase from 2 billion in 2000 to 4 billion in 2030 and to 5.5 billion in 2050.
- Among countries in the developing regions, the fastest growth in the urban population will occur in Sub-Saharan Africa, followed by South and Central Asia.
- The projected rate of increase in urban land cover will be higher than the rates of increase of the urban population because urban population densities can be expected to decline.

Figure 4.6 and table 4.4 show the increases in urban land cover in different world regions under the three density scenarios (for country projections see Angel et al. 2010c, table 4). At constant densities, the world's urban land cover will only double between 2000 and 2050 as the world's urban population doubles. At a 1 percent annual rate of density decline it will triple. At a 2 percent annual rate of decline it will increase more

TABLE 4.3
Urban Population Projections for World Regions, 2000–2050

Region	Urban Population (in thousands)										
	2000	Annual Growth Rate (%)	2010	Annual Growth Rate (%)	2020	Annual Growth Rate (%)	2030	Annual Growth Rate (%)	2040	Annual Growth Rate (%)	2050
Eastern Asia & the Pacific	517,808	2.67	676,086	2.05	829,877	1.43	957,030	0.91	1,047,771	0.53	1,105,254
Southeast Asia	206,683	3.27	286,579	2.44	365,769	1.84	439,465	1.42	506,485	1.03	561,580
South & Central Asia	406,151	2.51	522,270	2.72	685,217	2.7	897,250	2.32	1,132,092	1.89	1,368,296
Western Asia	163,087	2.22	203,587	2.03	249,445	1.67	294,920	1.38	338,476	1.08	377,265
Northern Africa	84,167	2.39	106,877	2.27	134,047	2.01	163,815	1.71	194,340	1.35	222,442
Sub-Saharan Africa	210,046	3.7	304,090	3.48	430,685	3.21	593,917	2.85	790,099	2.45	1,009,641
Latin America & the Caribbean	393,208	1.79	470,187	1.42	541,737	1.06	602,256	0.75	649,477	0.48	681,383
Europe & Japan	603,134	0.21	615,652	0.17	626,196	0.17	636,618	0.08	641,597	-0.04	638,840
Land-Rich Developed Countries	269,694	1.36	308,949	1.13	346,025	0.91	378,910	0.73	407,479	0.59	432,456
All Developing Countries	1,981,149	2.6	2,569,675	2.31	3,236,777	1.99	3,948,653	1.65	4,658,742	1.34	5,325,861
All Developed Countries	872,829	0.58	924,601	0.5	972,220	0.44	1,015,528	0.33	1,049,076	0.21	1,071,296
World Total	2,853,978	2.02	3,494,276	1.86	4,208,997	1.65	4,964,182	1.4	5,707,818	1.14	6,397,158

FIGURE 4.6
Projections of Urban Land Cover for World Regions, 2000–2050

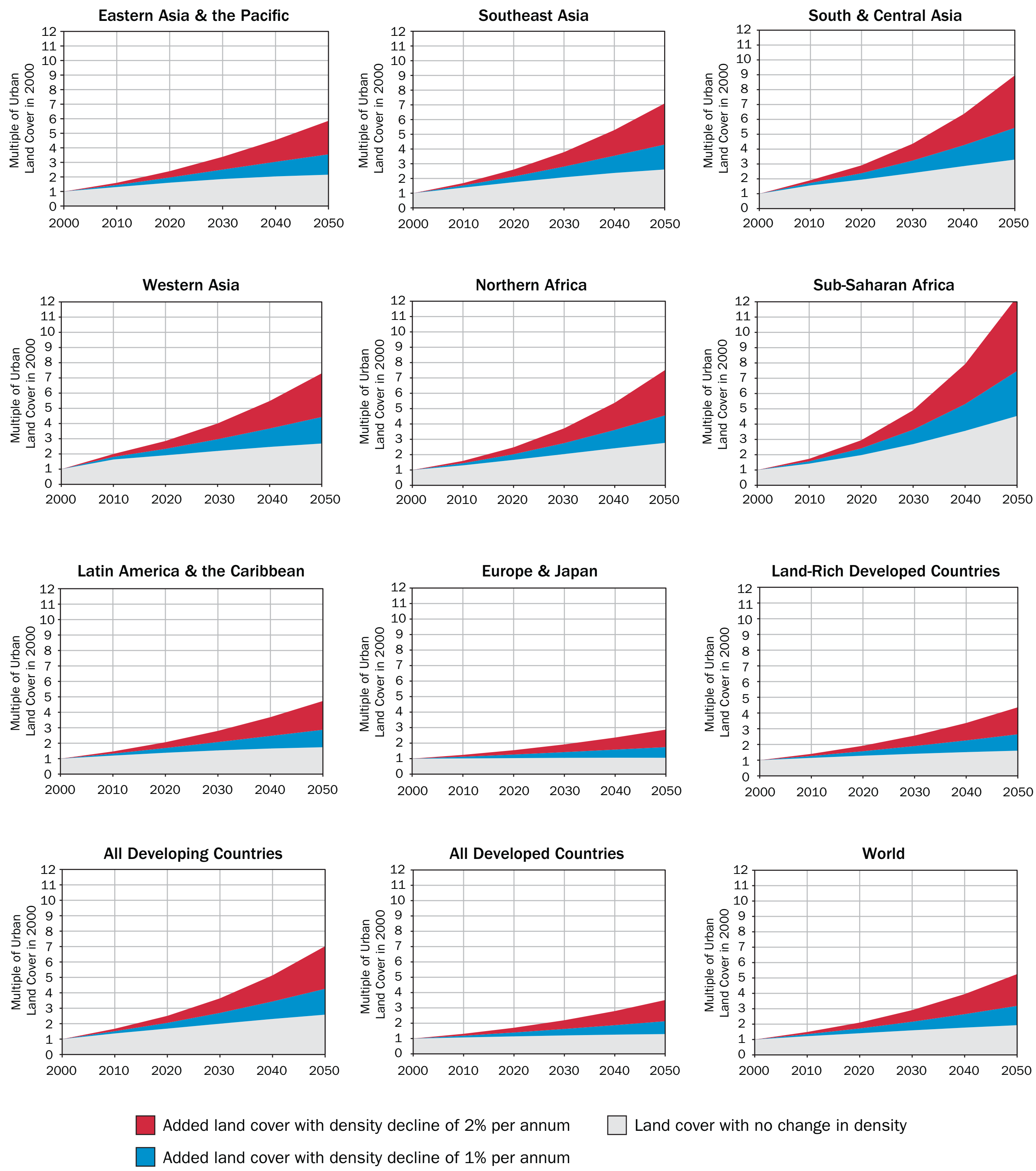


TABLE 4.4

Projections of Urban Land Cover for World Regions, 2000–2050

Region	Urban Land Cover, 2000 (km²)	Annual Density Decline (%)	Urban Land Cover Projections (km²)				
			2010	2020	2030	2040	2050
Eastern Asia & the Pacific	52,978	0	69,225	85,086	98,329	107,916	114,154
		1	76,505	103,925	132,730	160,991	188,208
		2	84,552	126,934	179,167	240,170	310,302
Southeast Asia	34,448	0	47,520	60,166	71,641	81,848	89,952
		1	52,518	73,487	96,705	122,103	148,306
		2	58,041	89,758	130,538	182,156	244,516
South & Central Asia	59,872	0	93,434	116,653	143,282	171,123	197,324
		1	103,261	142,480	193,410	255,286	325,332
		2	114,121	174,026	261,076	380,842	536,382
Western Asia	22,714	0	37,127	43,418	49,931	55,933	61,041
		1	41,032	53,031	67,400	83,442	100,639
		2	45,347	64,772	90,981	124,480	165,926
Northern Africa	12,104	0	15,782	20,093	24,676	29,277	33,519
		1	17,441	24,542	33,309	43,677	55,263
		2	19,276	29,975	44,962	65,158	91,113
Sub-Saharan Africa	26,500	0	37,568	52,304	71,375	94,325	120,182
		1	41,519	63,884	96,347	140,716	198,147
		2	45,886	78,028	130,054	209,924	326,689
Latin America & the Caribbean	91,300	0	109,552	126,218	140,209	151,227	158,925
		1	121,074	154,164	189,262	225,605	262,023
		2	133,807	188,296	255,477	336,563	432,002
Europe & Japan	174,514	0	177,635	180,569	183,661	185,162	184,439
		1	196,318	220,547	247,917	276,230	304,089
		2	216,964	269,377	334,653	412,086	501,358
Land-Rich Developed Countries	131,447	0	150,691	168,848	184,906	198,850	211,039
		1	166,539	206,232	249,597	296,649	347,944
		2	184,054	251,892	336,920	442,549	573,663
All Developing Countries	299,915	0	410,208	503,939	599,442	691,649	775,096
		1	453,350	615,512	809,163	1,031,819	1,277,918
		2	501,029	751,788	1,092,255	1,539,294	2,106,931
All Developed Countries	305,961	0	328,326	349,417	368,567	384,012	395,478
		1	362,856	426,779	497,513	572,879	652,033
		2	401,018	521,269	671,573	854,635	1,075,021
World Total	605,875	0	738,534	853,355	968,009	1,075,661	1,170,575
		1	816,206	1,042,291	1,306,676	1,604,698	1,929,951
		2	902,048	1,273,057	1,763,828	2,393,929	3,181,952

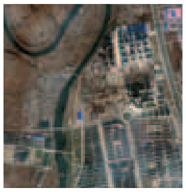
than five-fold. According to our high projection, urban land cover in Sub-Saharan Africa will expand at the fastest rate: more than 12-fold between 2000 and 2050.

If average urban densities in developed countries remain unchanged (low projection), then their urban land cover will grow by only 20 percent between 2000 and 2030 and by 29 percent between 2000 and 2050—from 300,000 km^2 in 2000 to 370,000 km^2 in 2030 and to 400,000 km^2 in 2050. Assuming that densities in the developed countries decline, on average, by only 1 percent per annum (medium projection), urban land cover will grow by 63 percent between 2000 and 2030, and by 113 percent between 2000 and 2050 —from 300,000 km^2 in 2000 to 500,000 km^2 in 2030 and to 650,000 km^2 in 2050.

In other words, at a 1 percent annual decline in average densities, urban land cover in developed countries will double in 50 years. If incomes continue to increase relative to gasoline prices and densities continue to decline at the rate of the 1990s, then urban land cover in developed countries will more than double between 2000 and 2030, and will triple between 2000 and 2050.

The situation is likely to be more critical in developing countries, where most urban population growth will take place. Assuming that their densities decline, on average, by only 1 percent per annum (medium projection), urban land cover will grow by 170 percent between 2000 and 2030, and by 326 percent between 2000 and 2050—from 300,000 km^2 in 2000 to 800,000 km^2 in 2030 and to 1,300,000 km^2 in 2050. Assuming that densities in developing countries decline, on average, by 2 percent per annum (high projection), urban land cover will grow by 264 percent between 2000 and 2030, and by 603 percent between 2000 and 2050 —from 300,000 km^2 in 2000 to 1,100,000 km^2 in 2030 and to 2,100,000 km^2 in 2050.

The projected urban expansion in all regions, especially the developing countries, in the coming decades should give pause to advocates of global urban containment. It is told that King Canute (1015–1035), annoyed by courtiers who told him he was an all-powerful king who could even hold back the tide, had his throne placed on the beach and ordered back the tide, only to get his feet wet. Heroic as it may be, and justified as it may be, containing the oncoming global urban expansion is much the same as holding back the tide.



CHAPTER 5

Conclusion: Making Room for a Planet of Cities

Activists protesting urban expansion in Surrey, England, 2009

The evidence presented in this report suggests that applying the urban containment paradigm on a global scale is not appropriate in many countries that are still urbanizing rapidly. This chapter explains why it is inappropriate, proposes an alternative paradigm for accommodating rather than containing urban expansion in these countries, and outlines the minimal requirements for putting this alternative paradigm into practice.

THE CONTAINMENT PARADIGM

Containment has been defined as follows: "Broadly speaking, urban containment programs can be distinguished from traditional approaches to land use regulation by the presence of policies that are explicitly designed to limit the development of land outside a defined urban area, while encouraging infill development and redevelopment inside the urban area" (Nelson, Sanchez, and Dawkins 2004, 342).

Urban containment, its advocates claim, is the antidote to sprawl. It can limit the growth of endless cities, increase urban population densities, reduce the excessive fragmentation of urban footprints, lessen car dependency, revitalize public transport, conserve farmland, protect nature, rejuvenate central cities, decrease the cost of infrastructure, save energy, and reduce carbon emissions.

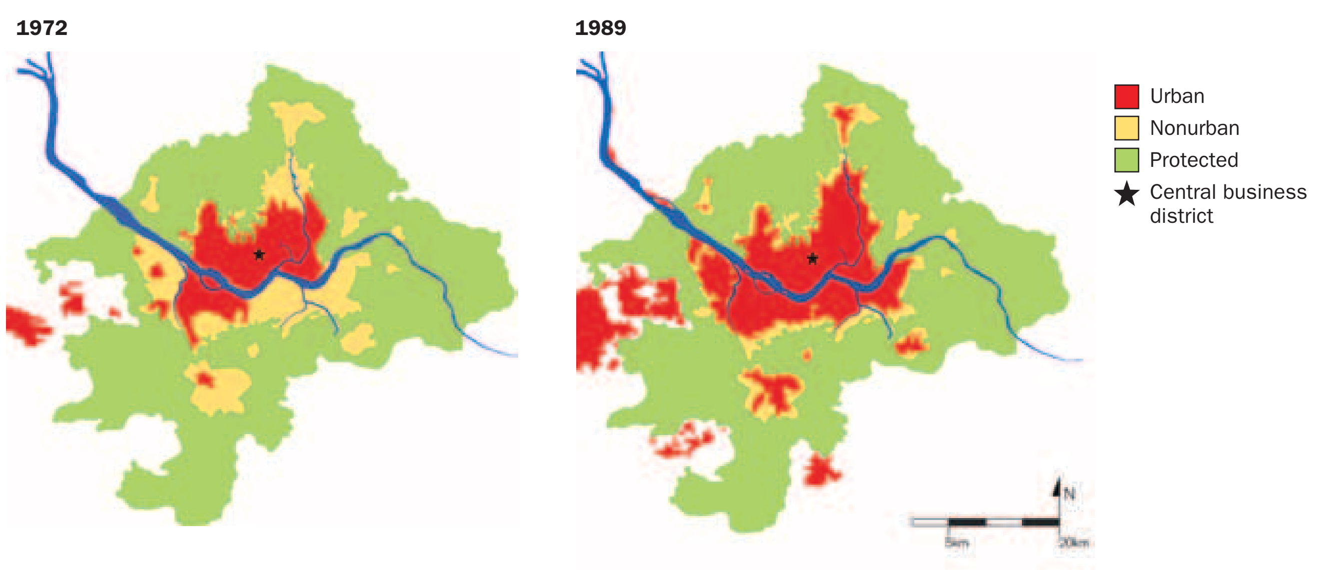
The containment paradigm can be traced back to the London Greenbelt Act of 1938 (Munton 1983) and the British Town and Country Planning Act of 1947, but the prime example of the paradigm is the greenbelt of Seoul, the capital of the Republic of Korea (see chapter 1). Established in 1971, Seoul's greenbelt rigorously prohibited the conversion of land to urban use in an area of 1,482 km^2 around the city. The area within the greenbelt amounted to 554 km^2 while the built-up area circa 1972 amounted to 206 km^2 (figure 5.1). In other words, the greenbelt did not impose a binding constraint on urban development when it was created. It enjoyed wide public support, insofar as it "prevented urban sprawl and functioned as a source of clean air and other environmental amenities" (Lee 1999, 43–44).

Yet, its promise aside, urban containment in Seoul and elsewhere has not escaped criticism. Its detractors have claimed that it restricts the supply of land, thereby increasing its price and making housing less affordable; ignores consumer preferences for living at lower densities or in garden suburbs; protects urban property values at the expense of rural landowners; and displaces urban development to satellite towns and edge cities outside the containment zone, thereby increasing rather than decreasing commuting distances, energy costs, and carbon emissions.

By 1989, the built-up area of Seoul expanded to almost fill the area inside the greenbelt, resulting in "an extreme shortage of affordable land for housing and rapid land price appreciation. The nominal land price in 1989 was 23 times the 1970 price" (Lee 1999, 43, quoting Choi 1993), while the real land price tripled. The house-price-to-income ratio in Seoul by 1990 was 9.3, the fifth highest and almost double the global average of 5.0 among 53 cities in 53 countries that year. The rent-to-income ratio was 0.35, the second highest and more than double the global average of 0.16 among the cities studied (Angel 2000, table A20, 367).

Advocates of containment have responded to criticisms in various ways—challenging the evidence that containment in and of itself leads to higher house prices; agreeing to periodically adjust the supply of land for development so as to avoid shortages and their concomitant land and housing price increases; making new claims (e.g., that containment reduces obesity or racial

FIGURE 5.1
Seoul, Korea's Greenbelt and its Built-up Area in 1972 and 1989



segregation); and incorporating regulations that facilitate the creation of affordable housing as integral parts of containment schemes. In their review of the evidence linking growth management and housing affordability, Nelson et al. (2002, iii) therefore conclude: "Properly designed growth management programs are ones that include policies that mitigate the adverse effects of urban growth and the adverse price effects on lower-income households."

Surely, containment in and of itself, and especially benign containment that seeks to ensure that land supply bottlenecks will be avoided by moving containment limits outwards at regular intervals, should not lead to higher house prices. Containment matters only if it is a binding constraint on land supplies. That is why Seoul's greenbelt did not affect house prices initially, but did affect them later, once the area within the greenbelt was largely built up.

Several of the rationales for containment—the protection of green areas from encroachment; the move toward a sustainable energy future; and the promised reduction of greenhouse gas emissions—are now global concerns that transcend international boundaries, as well as the administrative jurisdictions of cities and metropolitan areas. It is no surprise, therefore, that urban containment strategies are advocated increasingly on a global scale as strategies to be adopted everywhere, preferably in every city and country, if life on our planet is to be sustained.

This report argues that a clear distinction must be made between urbanized and urbanizing countries, and that the containment paradigm is ill-suited for urbanizing countries. We have defined urbanizing countries simply as countries that had an urban population growth rate higher than 1.5 percent per annum, to distinguish them from urbanized countries that had lower growth rates. We made a further distinction among urbanizing countries—minority-urban where less than half of the population lived in cities in 2000, and majority-urban where more than half of the population lived in cities in 2000.

Almost all industrialized or developed countries are in the urbanized countries category. All developing countries—except for Singapore, a third of the Latin American countries, and a few Central Asian countries—are in the two urbanizing country categories. Slightly more than one-third of the urban population of the world lived in urbanized countries in 2000, and two-thirds lived in urbanizing countries.

More important, however, 91 percent of the total growth in the urban population between 2010 and 2030 will be in urbanizing countries, of which 74 percent will be in the minority-urban category (e.g., India, China, and most of Southeast Asia) and 17 percent in the majority-urban category. Only 9 percent of the projected growth in the urban population will be in urbanized countries. Similar percentages are projected for the growth in the urban population between 2010 and 2050.

When the urban population of a country grows at 2.5 percent per year and average built-up area densities in that country decline at 1.5 percent per year—both realistic rates in many urbanizing countries—then cities will expand their land area at an average rate of 4 percent per year. At that rate, the country's urban areas will double in size in 17 years and triple in 27 years. Ensuring a 30-year land supply for urban expansion will require cities to prepare new areas equivalent to at least twice the existing area to accommodate the expected urban expansion, and to expand these areas on a regular basis every decade.

At the heart of the containment paradigm is the outright rejection of this business-as-usual model of urban expansion, and an unswerving commitment to refashion sprawling cities into compact ones driven by goals of sustainability, resource conservation, and the protection of the planet.

This may be an appropriate reaction in some (but not all) cities in land-rich developed countries like the United States, where densities in most metropolitan areas are so low they can hardly decline any further. These cities can no longer sustain public transport because their populations are growing very slowly if at all, and there are adequate vacant lands within existing city footprints to accommodate projected growth for decades. In these cities, a combination of regulations and incentives that accelerate infill and allow for the construction of mixed-use developments at higher densities, as well as for the densification of existing neighborhoods, may be a sensible urban development strategy.

WHY CONTAINMENT IS INAPPROPRIATE IN URBANIZING COUNTRIES

The insistence on containment is quite misplaced in cities that are still growing rapidly in population; where densities are already high and can decline appreciably while still sustaining public transport; and where vacant lands will be filled in and new ones formed several times over before the urbanization process comes to an end.

The exportation of the containment paradigm from the urbanized countries where it has taken root to urbanizing countries is therefore worrisome. The refusal to plan for urban expansion at declining densities in cities in urbanizing countries as a matter of principle—in the belief that expansion should not occur, in the hope that it will not occur, or due to a fear of those who of oppose it—may be a costly mistake and a recipe for failure. We offer five principal reasons why the urban containment paradigm is ill-suited for cities in urbanizing countries.

Tight-Fitting Boundaries

An *a priori* commitment to containment is likely to prevent planners in fast-growing cities from correctly assessing how much land will be needed for urban expansion at realistic densities and realistic levels of fragmentation in the coming decades. A firm commitment to plan for a smaller area in the hope that the city can be contained within it will also result in lower than necessary estimates of infrastructure needs and their associated investments.

Once containment boundaries become binding constraints on expansion, they are likely to exert inflationary pressure on land and housing prices, as they have in Seoul. In the longer term, if containment is successful, it is also likely to displace development beyond the no-development zones, leading to more spread out metropolitan areas with longer commutes, as it did in Seoul (Ahn and Ohn 1997) and in London (Hall et al. 1973).

Misplaced Hopes on Infill

Containment advocates typically insist that there are sufficient vacant lands in the urbanized open space within existing city footprints that can and should be filled in to accommodate growth. But, when growing cities expand several-fold, areas that were originally fragmented by vacant open space eventually get filled in while new fragmentation occurs farther out on the urban periphery.

We found that, as expected, fragmentation increases with distance from the city center. More specifically, the average distance from the city center to urbanized open space remained a fixed multiple of the average distance to the built-up area of the city as it expanded. Between 1990 and 2000, for example, the average distance from the city center to urbanized open space in the global sample of 120 cities increased from 10.3 to 12.0 kilometers, while the average distance from the city center to the built-up area of the city increased from 8.3 to 9.5 kilometers. The ratio of the two remained 1.3 and did not change significantly between the two periods: urbanized open space remained, on average, 30 percent further out than the city's built-up area.

We also found that half of all new development between 1990 and 2000 was infill and the rest was extension and leapfrog development. There was also a lower bound on infill. A typical city in the global sample contained open space in and around the city equivalent to at least 40 percent of its built-up area. An average city contained more than double that amount. Fragmentation, in other words, is an inherent characteristic of the spatial structure of cities. Assuming that all vacant lands will eventually be filled in is a pipedream that will also lead to underestimating land and infrastructure needs, resulting in laissez-faire expansion on the urban periphery.

Unnecessary Densification

The urban containment credo goes hand-in-hand with the compact city credo: that is, densities should be increased to make cities more compact. But average city densities in most urbanizing countries are typically high enough to sustain public transport and there is no need to make them denser. In fact, in several places densities are clearly too high, and there are great social benefits to be gained from decongesting them, much like the gains from suburbaniza-tion of the industrial cities of the nineteenth century (see box 2.1). Environmentalist Stewart Brand (2010) recently touted the exceptionally high densities in Dharavi, Mumbai's largest slum, as a best practice example of "How Slums Could Save the Planet." We believe that view to be erroneous.

Dharavi, the largest slum in Mumbai, India, 2007

In many cities in urbanizing countries, densities can decline for decades while still remaining high enough to sustain public transport, especially in poorer countries where car ownership is likely to be the exception rather than the rule and where informal transit service abounds. Studies relating density to transit use (e.g., Pushkarev and Zupan 1982) suggest that in countries like the United States with high levels of car ownership, a density of 30 persons per hectare is required to sustain a minimum level of regular public transport.

The average built-up area density in cities in developing counties in 2000 was 129 p/ha. Even if it declined at 2 percent per annum, the most pessimistic scenario, it will still be 47 p/ha in 2050, more than double the average built-up area density in U.S. cities in 2000 (21 p/ha), and—given expected lower levels of car ownership—high enough to sustain both public transport and informal transit services.

Overreliance on Regulation

Many urbanizing countries have weak enforcement regimes that are unable to constrain urban expansion effectively by relying on land use regulations that are largely ignored or circumvented by both formal developers and informal settlers.

Figure 5.2 shows planning zones in San Salvador, the capital of El Salvador, when its greenbelt was introduced in 1999. By 2001, only 151 hectares were built upon in the area designated urban, while 220 hectares were added to protected green areas and 115 hectares to seismic zones (Sheppard 2004). The total area of illegal urban development was more than twice the area of legal development within zones designated for urban expansion. In short, in the absence of effective enforcement, a failed containment scheme will result in problematic laissez-faire expansion.

One of the more unfortunate consequences of ambitious containment schemes that fail to take hold is the near disappearance of protected open space in large swaths of metropolitan areas, resulting in the creation of "endless" cities—the type of cities that containment was originally meant to prevent. By seeking to protect the entire countryside surrounding the city, urban dwellers end up with little or no access to protected open spaces at all. São Paulo is the classical example with the lowest score on the openness index (0.18) in 2000 in the global sample of 120 cities (figure 5.3). The main area of the city, approximately 1,300 km^2, was nearly devoid of open spaces.

The most common tool for protecting open spaces from development are land use regulations that seek to prevent (or postpone) the conversion of privately owned rural land to urban use. These regulations are typically resisted by rural landowners who want to maximize profits from the sale of their lands, as well as by urban dwellers seeking cheap lands on the urban fringe in proximity to the open countryside.

If land use regulations are not binding or cannot survive under pressure, they are likely to be ignored. The result is that all rural land may be converted to urban use and built upon sooner or later. With the evolution of land markets on the urban fringes of cities the world over, it is becoming more difficult to justify and maintain long-term prohibitions that prevent rural landowners from converting their properties to urban use, in order to create recreational and environmental (and therefore financial) benefits for city dwellers. In the long-run, the likely

FIGURE 5.2
Planning Zones in San Salvador, El Salvador, 1999

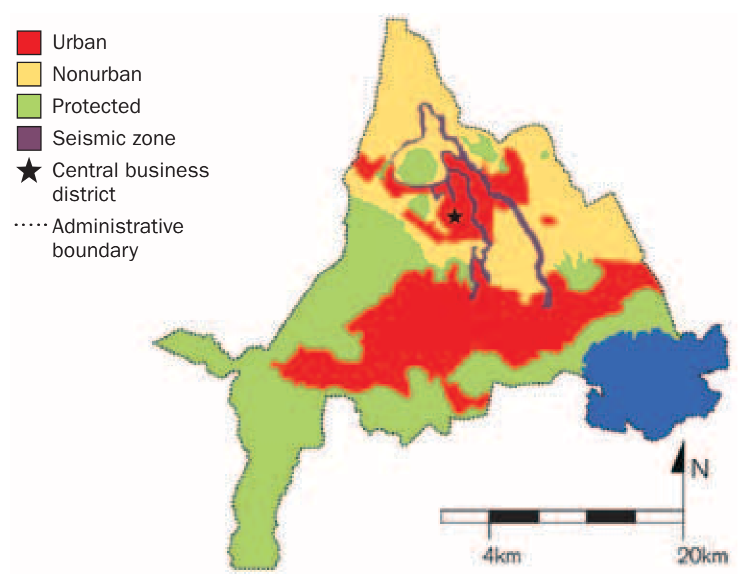
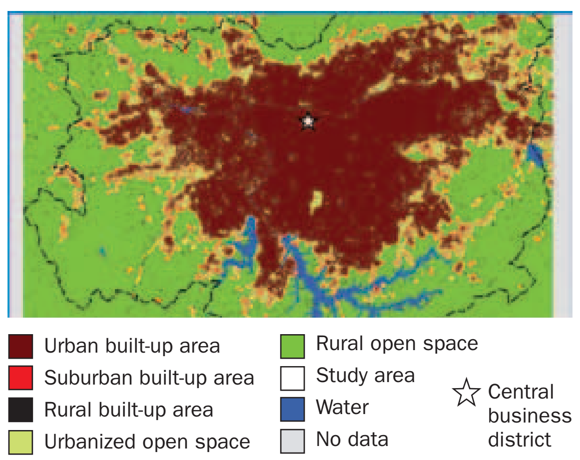


FIGURE 5.3
The City Footprint of São Paulo, Brazil, 2000



result is laissez-faire expansion with little or no open space that remains in permanent use as open space.

Undersupply of Arterial Roads

Another serious problem associated with failed containment schemes that result in laissez-faire expansion—or with the absence of effective public engagement with planning for expansion altogether—is the undersupply of arterial roads (Angel 2008a). The road network in every country typically forms a three-tier hierarchy of primary, secondary, and tertiary roads. Central or state governments usually plan, finance, construct, and maintain the primary intercity road network that connects the country together. Municipalities typically plan, finance, construct, and maintain their secondary or arterial road networks that carry public transport and trunk infrastructure. Private developers of residential neighborhoods or of commercial, office, and industrial projects typically plan, finance, and construct the tertiary roads that serve buildings within their projects.

Arterial roads are classic public goods (i.e., users cannot be effectively excluded from using them) and they need to be financed by municipal budgets. Given the strained budgets of municipalities in developing countries and their limited ability to borrow funds, it is no wonder that the arterial road network in urban areas is typically undersupplied.

FIGURE 5.4
The Absence of Arterial Roads in Bangkok, Thailand, 1984

The hands-off, laissez-faire approach to urban development that characterizes Bangkok illustrates how the absence of arterial roads creates large efficiency losses and stymies organized urban expansion. Figure 5.4 shows the pattern of narrow lanes in a large area of a northeastern inner suburb of Bangkok that was developed during the 1960s and 1970s. This example underscores one of the drawbacks of laissez-faire development: the arterial roads are spaced some 8 kilometers apart. Congestion is increased as the longer intracity trips are crowded into a small number of main roads. Increased congestion on Bangkok's arterial roads results in increased air pollution, increased energy use, and decreased labor productivity.

The preponderance of evidence presented in this report suggests that the massive expansion of cities and metropolitan areas in urbanizing countries cannot be contained, and that efforts at containment are likely to fail, resulting in inefficient, inequitable, and unsustainable laissez-faire expansion. Since neither containment nor laissez-faire expansion is appropriate for urbanizing countries, we introduce an alternative para-

Congestion on arterial roads in Bangkok, Thailand, 2009

digm for guiding urban expansion in these countries in the coming decades.

THE MAKING ROOM PARADIGM

This paradigm is grounded in the conviction that we need to make at least minimal preparations for the sustainable growth and expansion of cities in urbanizing countries rather than to constrict and contain them. It calls for accommodation and rejects the placement of limits on urban expansion that are likely to fail or, if they succeed, will do more harm than good. The paradigm consists of four key components:

1. Realistic projections of urban land needs;
2. Generous metropolitan limits;
3. Selective protection of open space; and
4. An arterial grid of roads at one kilometer apart.

Realistic Projections of Urban Land Needs

Plans for the expansion of New York City and Barcelona offer excellent examples of realistic projections of urban land needs (figures 5.5 and 5.6).

In 1811, when New York City had only 100,000 people crowded into the southern tip of the island of Manhattan, three city commissioners—Gouverneur Morris, John Rutherford, and Simeon De Witt—introduced an expansion plan based on a regular street grid to prepare for a 10-fold increase in the city's population. In presenting their now-famous plan, the commissioners remarked: "To some it may be a matter of surprise that the whole island has not been laid out as a city. To others it may be a subject of merriment that the commissioners have provided space for any population that is collected at any spot on this side of China" (Mackay 1987, 20).

In Barcelona the city council organized a competition in 1859 for a similar plan to expand that city and subsequently selected the visionary design submitted by Ildefons Cerdá as its winning entry (Soria y Puig 1999). Cerdá also envisioned a 10-fold

FIGURE 5.5
The Commissioners' Plan for the Expansion of New York City, approved 1811

expansion of the existing city that then had a population of 150,000. Like the New York City commissioners, Cerdá focused on a practical vision and was intimately involved in devising the legal, administrative, and financial instruments necessary for implementation.

Being a realist, Cerdá was very critical of utopian dreams: "In our times we have seen some dazzlingly brilliant utopias appear, and they really have shown and dazzled, but simply in the manner of a fleeting bolt of lightening, and they have left no trace behind. Some hard and rather costly lessons brought skepticism to seep into the hearts of our societies, and now only patent proofs of non-remote possibilities can sweep away the doubts, distrust, and lack of confidence" (Soria y Puig 1999, 375).

Neither of these city plans was a utopian dream, and both were quickly implemented. But both cities soon outgrew their plans and no subsequent plans were developed. Furthermore, our research could not identify any urban plans in recent decades that would have allowed for such generous expansion of metropolitan areas, although the 30 cities in our representative global sample actually expanded 16-fold in a matter of 70 years during the twentieth century.

This absence of planning may be a failure of imagination or a failure of nerve, but such a vision is exactly what will be required to make realistic projections and practical plans for the expansion of many cities in urbanizing countries in the coming decades.

Figure 5.7 graphs our estimates of the projected increase of the 2000 urban land cover in all countries by 2050 under three density scenarios. Under the 1 percent annual density decline scenario, 22 countries will have their urban land cover multiplied 10-fold or more between 2000 and 2050. Under the 2 percent annual density decline scenario, 47 countries will be in this situation.

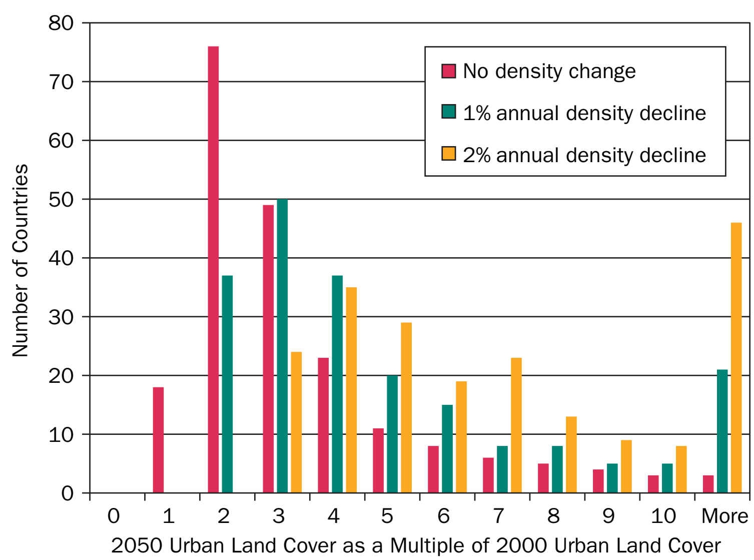
FIGURE 5.6
Ildefons Cerdá's Ensanche Plan for the Expansion of Barcelona, Spain, 1859

Thus, the 10-fold New York City and Barcelona projections may not be unrealistic, after all, for cities in many urbanizing countries.

The ability to project urban land cover at the country level, limited as it may be, does not extend to either population or urban land cover in individual cities, where growth is much less predictable. There is always a small probability that a given city will grow into a very large one. Taleb (2007, 208–211), who has studied the impact of improbable events, suggests that the appropriate strategy is to confront this uncertainty by focusing on its consequences rather than its likelihood: "Invest in preparedness, not in prediction. . . The probabilities of very rare events are not computable. . . We can have a clear idea of the consequences of an event, even if we do not know how likely it is to occur. . . All you have to do is mitigate the consequences."

This suggests that erring on the high side of projecting urban land cover in a particular city expansion plan may be the correct strategy to reduce the risk of laissez-faire expansion,

FIGURE 5.7
Number of Countries with Various Multiples of Their 2000 Urban Land Cover by 2050



as long as the cost of putting these preparations into practice is kept at a minimum.

Generous Metropolitan Limits

Urban land cover projections, even those by sophisticated demographers willing to err on the high side, will be of little use unless they are put into practice by designating urban growth boundaries and enshrining them in law at the state, provincial, or national level. Cities are powerless to plan for their expansion, as are metropolitan areas containing large numbers of independent municipalities. Just as the New York City plan was authorized by the State of New York, and Portland's urban growth boundary was authorized by the State of Oregon, new metropolitan boundaries remain a concern and a responsibility of higher levels of government.

The main and crucial difference between Portland's boundary and the designation of appropriate city limits to make room for future growth is a matter of generosity. Metropolitan limits have to be large enough to accommodate 20 to 30 years of urban expansion based on realistic projections of population growth, density decline, and changes in fragmentation levels.

If they are to err, they should err on the side of more rather than less, to allow for the small probability that the city may become very large. After being put into law, these metropolitan limits—designating areas where orderly urban development is allowed and encouraged—should be subject to review and changed regularly, preferably every five years, as population, density, and fragmentation trends become better understood.

Land prices on the urban periphery are always subject to speculation, and once they become inflated it takes them considerable time to decline, even if land shortages are no longer an issue. Speculation leading to high land prices on the urban fringe can only be avoided if limits on urban expansion are generous enough and credible enough to ensure that land will be in plentiful supply for years to come, and that hoarding it will not be profitable in the long run.

In Chinese cities, for example, current real estate values are exorbitant. In July 2009 a developer reportedly paid US$446.5 million for 21 hectares of suburban land in Shanghai, an average price of $21 million per hectare ($8.5 million per acre) (*The Wall Street Journal* 2009). These high land prices are a testimony to the lack of investor confidence in the ability of the Chinese government to ensure an adequate supply of land for urban expansion in the future, even though the Chinese government has set very generous limits to its metropolitan areas.

In 1999 the administrative area of Beijing was 11 times larger than its built-up area, leaving more than enough room for its projected urban expansion (see figure 1.4). It should serve as a best practice example of the generous metropolitan limits that this report advocates. The problem in China, of course, is that converting land from rural to urban use within metropolitan limits is strictly controlled to protect the country's food security (see chapter 3).

While projecting the realistic land needs of urban areas is an important first step in making room for urban expansion, only the creation of generous urban growth boundaries for metropolitan expansion and enshrining them in state, provincial, or national law can initiate the necessary legal framework for orderly growth. This framework need not necessarily mandate new structures of governance within the areas of metropolitan expansion, but it does need to limit the power of governments at all levels to block the conversion of land from rural to urban use in areas designated for urban expansion.

Raised eco-walk in an urban forest park in Singapore, 2009

Selective Protection of Open Space

There is no question that urban dwellers around the world put a value on proximity to open space. Homes adjacent to or within walking distance of parks and playgrounds command higher prices, and people who move to the outer suburbs often cite their desire to be closer to the open countryside as a reason for their move.

Singapore has an enviable hierarchy of large and small urban parks distributed throughout the city-state area of 710 km^2, including nature and riverine parks, city and heritage parks, and botanic gardens. These parks are clearly in permanent use as open space, and are available for all urban dwellers. Not every city can institute a publicly accessible open space hierarchy within its city footprint comparable to that of Singapore, but many cities could create permanent public open spaces in designated areas of expansion, where land is still inexpensive and in ample supply.

The selective protection of open spaces involves four key steps:

1. Creation of a metropolitan open space plan that contains a hierarchy of open spaces of all sizes and types—from football fields and playgrounds to wetlands, farms, and nature parks—in areas of expansion;
2. Passage of new regulations or enforcement of existing regulations that mandate the allocation of a certain share of all private lands for public use;
3. Purchase of private lands for use as public open space on the urban periphery while land prices are low; registration of liens on private lands designated for future use as open space; or acquisition of the development rights to land through purchase or exchange of land rights; and
4. Creation of an institutional framework comprising public, private, and civic organizations for the aggressive protection of these open spaces from invasion by formal and informal developers.

The most important aspect of this open space component of the making room paradigm is that its actual extent will be limited by the private, public, and civic resources—both financial and human—that can be made available for its implementation. That is why it must be selective. Instead of seeking to protect too much land from development at no cost to the public, failing in the attempt, and ending up with no open space at all, this strategy aims to protect some land at a minimal cost to the public so it remains open in perpetuity.

Furthermore, this approach does not rely on a regulatory regime that penalizes some landowners on the urban fringe by prohibiting them from developing their land for urban use. Instead, it takes as a given that owners of land in fringe areas designated for urban expansion have the right to use their land in accordance with the laws governing urban development, subject to their willingness—enshrined in enforceable regulations—to forego a part of their land for public use, already a common practice in many countries from Israel to Ecuador.

In addition, by opening up large areas for urban development, this approach aims to vastly reduce the premium typically associated with the conversion of land from rural to urban use, thus keeping land prices on the urban fringe low and enabling the purchase of land for public use or the purchase of development rights from landowners by land conservancies to ensure that their lands remains open in perpetuity.

In short, instead of a greenbelt on the periphery of the city, the making room paradigm opts for a green city full of varied open spaces. Instead of surrounding the city with a greenbelt that aims to contain its inevitable expansion and likely failing in the attempt, this strategy calls for built-up areas and open spaces to interpenetrate each other as the city expands outwards.

An Arterial Grid of Roads

Assuming that the objections to expansion can be overcome, the obstacles to a new urban boundary can be surmounted, and that designated green areas can be effectively protected from urban encroachment, the question arises: What needs to be done, at a minimum, to prepare new lands for urban use (Angel 2008a)? The answer in urbanizing countries is straightforward: to secure the rights-of-way for an entire arterial road and infrastructure grid in the area within these new administrative boundaries.

The arterial grid pertains only to the network of major arterial roads—the urban roads that typically carry intraurban traffic, public transport, and trunk infrastructure, especially water and sewer lines. The main difference between an arterial grid and the local street grid can be seen in Detroit, Michigan, where the arterial grid encompasses 1.6-km-wide urban superblocks with local streets that can be arranged in various ways to provide access to all plots (figure 5.8).

To accommodate urban expansion, an arterial grid on the urban fringe must have five essential properties.

1. *Total coverage:* The grid must cover the entire area designated for expansion in the next 20 to 30 years, not just a segment of that area.
2. *Connectivity:* The grid should be a mesh of long, continuous roads that crisscross the expansion area and connect it to the existing road network.
3. *One kilometer spacing:* To ensure that public transport is within a 10-minute walk, these roads should be spaced no more than one kilometer apart.
4. *Wide right-of-way:* The width of the roads should be of the order of 20–30 meters, so they can have designated bus lanes, bike paths, a median, and several lanes to carry intracity traffic and yet be convenient for pedestrians to cross safely.

5. *Progressive improvement:* Initially, only rights-of-way for the grid should be acquired by municipal authorities. Selected segments can be paved in future years as demand requires and as budgets become available.

The early introduction of an arterial grid into expansion areas would help attain five important objectives.

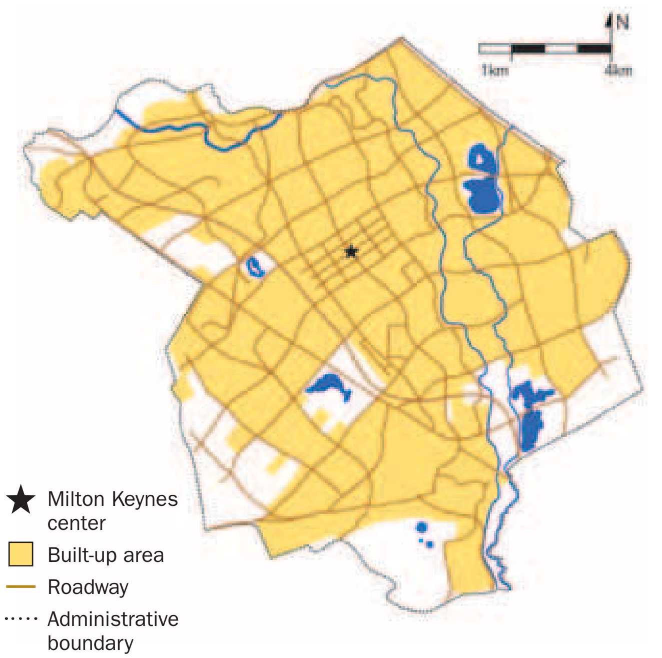
An antipoverty objective. The proposed arterial grid is meant to open up sufficiently large areas for urban expansion to ensure that land supply is not constricted, and that large numbers of residential plots remain affordable. In contrast to earlier affordable housing strategies in developing countries that focused on the provision of a limited supply of individual plots—commonly referred to as sites-and-services projects—the proposed strategy aims to provide a large number of superblocks that can then be subdivided by formal and informal developers into individual plots. To create the desired impact of the proposed arterial grid on the urban land market, the entire network should be initiated early, with individual road segments being improved to higher standards as demand for travel along them increases.

This strategy minimizes the risk of land speculation that typically occurs when only a few fully paved roads are put in place, as well as the risk of paving roads at the wrong time and in the wrong places. In a land pooling and readjustment scheme, for example, when only a portion of the rural periphery is converted to urban use and a full complement of infrastructure services is introduced, then land prices increase dramatically, rendering access to the scheme beyond reach for the urban poor (Larsson 1993). Only a comprehensive approach to the land supply issue can keep land prices in metropolitan areas from rising steeply, especially in rapidly urbanizing cities where there is strong demand for land.

FIGURE 5.8
Detroit, Michigan's One-Mile Arterial Grid, 1989

A planning objective. Urban infrastructure plans and investments in cities in urbanizing countries typically follow rather than guide urban expansion. Developers pressure municipalities to extend infrastructure services in piecemeal fashion to areas that the developers have chosen, often blatantly disregarding municipal plans. The arterial road grid would function as a basic framework for planning the city. Participatory planning would be considerably more effective if it focused on an individual superblock rather than on the metropolitan area as a whole. By locating the grid before development begins, municipalities can actively shape growth in the future. They will then be leading the developers into new areas rather than following them.

FIGURE 5.9
The Arterial Grid of Milton Keynes, England, with all its Arterial Roads Carrying Public Transport



The arterial grid plan simply assumes that, no matter how the city develops, it will need an underlying network of arterial roads to carry its traffic and trunk infrastructure. Unlike a typical master plan, it does not designate land uses or densities, nor does it recommend strategies for the economic, social, or cultural development of the city. Its design and implementation do not therefore require great expertise or brilliant ingenuity. In most cases the plan can be undertaken by municipal planners without outside help.

A transport objective. For an arterial grid to function as the road network for a public transport system three conditions must hold: (1) residential densities must be sufficiently high to sustain public transport; (2) the roads need to be spaced not more than one kilometer apart, so the great majority of people can walk to a bus stop from any location in less than 10 minutes, as in Milton Keynes (figure 5.9); and (3) the width of the rights-of-way for the roads needs to be on the order of 20–30 meters.

While the absence of an arterial grid may prevent the introduction of an effective public transport system that extends far into the urban fringe, putting in place an arterial road grid is not a guarantee, in and of itself, that the grid would be used effectively to carry public transport. Unless strong and enduring political alliances take effective steps to introduce and strengthen public transport alternatives to individual automobile travel, the appropriation of the arterial grid by cars and trucks—to the exclusion of busses, bicycles, or other environmentally friendly forms of transport—should come as no surprise.

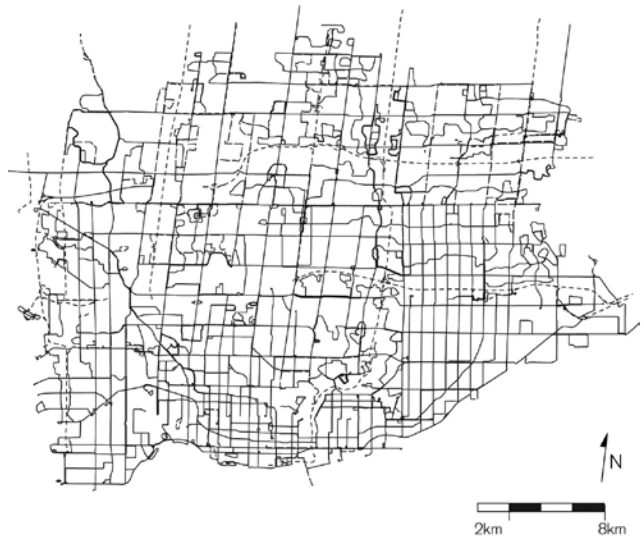
Toronto is one city that has been able to build and maintain an effective public transport system that extends along an arterial road grid far into the suburbs, and it now boasts the third-largest transit system in North America (figure 5.10).

An environmental objective. To the extent that a good public urban transport system can reduce our future reliance on private automobile travel, the arterial grid provides an essential building block in meeting the goal of reducing our carbon footprint. The organization of the urban periphery into a set of superblocks will also increase the chances that environmental justice concerns will be addressed. The superblock system created by the arterial road network also makes it possible to demand and ensure that each superblock contains an adequate amount of public open space; that environmentally unfriendly facilities are evenly distributed; and that human-scale communities and neighborhoods have a say in the planning, designing, and making of their physical environment.

Finally, to the extent that location within the planned superblocks with access to arterial roads is perceived as an advantage by formal and informal developers alike, the arterial grid will provide planners with an effective tool for directing urban development away from low-lying areas that will be vulnerable to future flooding as sea levels rise, or away from sensitive natural habitats that are likely to be encroached upon otherwise. This objective will be particularly important in cities where the regulatory regime by itself is incapable of preventing the conversion of rural peripheral lands to urban use.

A financial objective. Budget constraints typically prevent putting in place a completed arterial road network incorporating a system of well-paved, well-drained, well-lit, and signed roads in advance of development. That said, cities in rapidly urbanizing countries can acquire the land needed for such a network now, and then individual road segments can be improved to higher standards as demand increases. If demand along a particular road segment never increases, no great harm was done. If demand does increase, it can be met at a cost several decimal orders

FIGURE 5.10
Toronto, Canada's Bus and Streetcar Network, Located Largely on its Arterial Road Grid, 2010



Streetcars in winter, Toronto, Canada

of magnitude lower than putting an arterial road through a fully built neighborhood. This is the essence of the strategy proposed by Taleb (2007) for mitigating the uncertain consequences of unforeseen expansion at the lowest possible cost.

What does initiating the advance acquisition of the arterial road network now mean in practice? There is no global ready-made answer, but the case of Milagro, Ecuador, offers an example (box 5.1).

Special care must be taken to ensure that once land is transferred from private to public use to serve as a right-of-way for an arterial road it will not be occupied by squatters. This occurred in Quezon City, a city within metropolitan Manila in the Philippines, where an entire section of the right-of-way

BOX 5.1

The Planned Grid of Arterial Roads in Milagro, Ecuador

In an attempt to prepare their cities to accommodate expected population growth, municipal officials from seven intermediate-sized cities in Ecuador, including Milagro (figure 5.11), proposed various types of arterial grids in expansion areas (Angel 2008b).

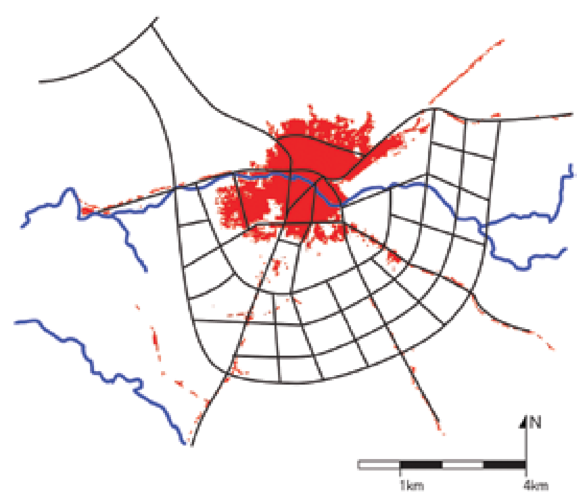
Ecuador's Municipal Law provides two important legal tools that enable municipalities to acquire land for roads and other public uses without compensation. One is a regulation that allows municipalities to obtain for public use up to 35 percent of any land being urbanized at no cost, once landowners decide to develop their land (Government of Ecuador 2004, Art. 237.3.b). The second legal tool is a regulation allowing the municipality to obtain up to 10 percent of the area of any land parcel, free of charge, for use as a right-of-way for public works (Government of Ecuador 2004, Art. 238).

In preparing a financial plan for acquiring the rights-of-way for the arterial grid, local planners in Milagro and other intermediary cities in Ecuador agreed that one-hectare areas will be acquired for all intersections through negotiation or marked as liens on property titles, and that three-meter-wide strips along both edges of each road will be obtained, typically free of charge in large land parcels and at market value in smaller ones.

In mid-2006, the average size of rural properties in Canton Milagro was 5.8 hectares, and the price of one hectare of agricultural land on the rural periphery of the city was $4,000 (Municipality of Milagro 2006). Subdivided land cost almost ten times as much. The median price for the land needed for the intersections may be on the order of

FIGURE 5.11

The Proposed Arterial Grid in the Expansion Areas of Milagro, Ecuador, 2007



$10,000 per hectare. The cost of the outright purchase of one-hectare plots for 100 intersections may thus be around $1 million, but many of these areas need not be purchased outright since municipal law permits the government to register liens on the relevant titles.

Admittedly, Milagro is a small town of some 50,000 people, and the same program in a city of 1,000,000 people may cost 100 times that amount. Still, the costs involved in bringing such a project to fruition in Milagro and elsewhere are miniscule in comparison to its projected benefits.

of Republic Avenue was settled, completely frustrating the plan for the avenue. There is no easy way to avoid this outcome, and each city that chooses to follow this path must carefully consider this possibility and embrace effective means to guard against it.

CONCLUSIONS

This report proposes that there is an effective, equitable, and sustainable way for the public sector to engage in the great process of urbanization now taking place in many developing countries. It involves the abandonment of the prevailing containment paradigm as irrelevant and ill-suited for cities that are scheduled to grow several-fold in coming decades. The adoption of an alternative making room paradigm offers an urban development strategy that aims to accommodate urban population growth rather than constrict and constrain it.

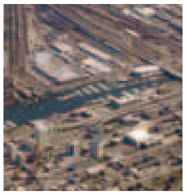
The making room paradigm is not laissez-faire in the sense of allowing market forces to determine the shape of the cities in the future. It recognizes the importance of markets in the development of urban lands for residential, economic, and civic activities, but it also recognizes their drawbacks—their inability to ensure the creation of a hierarchy of public and private open spaces protected in perpetuity, or to establish an adequate network of arterial roads to make cities sustainable through efficient public transport.

Our research into urban expansion in a global and historical framework has helped establish the basic parameters and dimensions of the expansion process. We now know that densities have been in persistent decline for a century or more, and we can expect them to continue to decline as long as incomes increase and transport remains relatively inexpensive. We also know that city footprints contain open spaces in and around built-up areas that are equivalent in size to those areas. While the share of open space within city footprints is in slow decline, the footprints themselves are still expanding rapidly.

We can now estimate the total urban land cover in all countries and, given these estimates together with population projections and realistic assumptions on density decline, we can now project the amount of land that will be needed to accommodate urban populations in all countries between 2000 and 2050.

This policy focus report therefore provides both the conceptual framework and the basic empirical data necessary for the minimal yet meaningful control of the urban expansion process. Our evidence, analysis, and conclusions can help lay the foundation for a fruitful discussion of the fate of our cities, and of our planet, as we seek to come to terms with the urbanization process.

Squatters occupying the right-of-way on Republic Avenue in Quezon City, Metro Manila, The Philippines



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Making Room for a Planet of Cities

The prevailing urban planning paradigm now guiding the expansion of cities and metropolitan areas is premised on the containment of urban sprawl, but containment is not appropriate in rapidly urbanizing countries where most growth in now taking place. Our analysis of the quantitative dimensions of past, present, and future urban land cover suggests a different paradigm—the making room paradigm—as a more realistic strategy for cities and metropolitan regions that need to prepare for their inevitable expansion.

This policy focus report seeks to enrich our understanding of the context in which preparations for urban expansion must take place in cities around the world using empirical data on key parameters that characterize their spatial structure and its changes over time. Carefully selected metrics measured in four new data sets with ArcGIS software now allow us to construct a comprehensive and consistent global and historical perspective on urban expansion.

This report also examines three discrete attributes of urban spatial structure and their change over time: density, the average population density of the built-up area; fragmentation, the amount of open space in and around cities that is fragmented by their built-up areas; and urban land cover, the total land area occupied by cities. While these attributes are correlated with each other, they measure different phenomena. Measured over time these attributes provide a relatively comprehensive characterization of urban expansion worldwide.

The proposed making room paradigm is grounded in the conviction that we need to prepare for the sustainable growth and expansion of cities in rapidly urbanizing countries rather than seek to constrict and contain them. This alternative paradigm consists of four key components:

1. realistic projections of urban land needs;
2. generous metropolitan limits;
3. selective protection of open space; and
4. an arterial grid of roads at one kilometer apart.

This report provides both the conceptual framework and, for the first time, the basic empirical data and quantitative dimensions of past, present, and future urban expansion in cities around the world that are necessary for making minimal preparations for future growth. At the very least, the report lays the foundation for fruitful discussion of the fate of our cities and our planet as we seek to identify and employ appropriate strategies for managing urban expansion at sustainable densities.

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