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THE SPATIAL DISTRIBUTION OF LAND PRICES AND DENSITIES:

The Models Developed by Economists

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ABSTRACT

Many planners believe that population densities can be fixed by design as cities expand. Many urban development plans aim at compact cities growth. However, compact cities are possible only with very high land prices produced by constraints on land supply. In this paper I show that the spatial distribution of land prices and densities are closely correlated and that they follow a predictable pattern produced by market forces. By using models developed by economists, planners could better understand both the pattern of densities in existing cities and how these densities are likely to respond to changes in size of population, households' income, and transportation speed and cost. I provide operational examples showing how planners can use economic models to project land and infrastructure needs for urban expansion. Using the master plan of Hanoi as an example, I show that disregarding the predictable forces exerted by the labor and land market results in poor chances for implementation and a misallocation of infrastructure investments. I conclude by showing the important role planners can play in designing infrastructure and land regulations once they have understood the mechanisms driving urban labor and land markets.

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We have seen that markets are responsible for population densities. High demand for a specific location increases density while low demand decreases it. Density is an indicator of land consumption, reflecting the equilibrium between supply and demand for land in a specific location. Population density is therefore an indicator dependent on market parameters, mainly households' income, land supply elasticity, and transport speed and cost.

In more simple terms, densities reflect the preferences of consumers when they have to make a choice between variously priced options. Large density variations within the same city reflect the diversity of households' preferences. This diversity reflects income differences between households but it also reflects different choices made by households of similar incomes but different urban environments – inner city or suburb, for example.

Planners, therefore, cannot impose densities through design. However, planners need to be able to project population densities based on their understanding of markets and consumers' preferences. Planners' ability to project densities as accurately as possible is important; an accurate projection will greatly facilitate the design of infrastructure and community facilities. However, planners should be aware that markets are subject to external shocks that nobody can anticipate and that their projections are only educated guesses at best. They should abstain from freezing their density projections into land use regulations and they should be prepared to adjust the capacity of the already-built infrastructure to the density created by markets.

To anticipate the likely densities generated by markets, planners should have a good understanding of the way land markets work. Markets do not work in mysterious ways. For instance, increasing households' income or decreasing land supply has consequences on housing prices that economists can easily anticipate. When markets are submitted to unanticipated external shocks – say, a sudden variation in gasoline prices – the impact on urban spatial structures is not immediate and planners have time to adjust their projections, providing they understand the implications of the changes.

In this working paper I will show that the spatial distribution of densities within cities – where the highs and the lows are located – is usually predictable thanks to the contributions of urban economists. The predictability of market forces and the peril of ignoring them is the main operational message of this paper. Economists have contributed greatly to this predictability by enhancing our understanding of the spatial patterns caused by land market mechanisms. Urban economists have developed a family of mathematical models that predict relationships between location, land rent, and quantity of land consumed. The predictive quality of these theoretical models – in spite of being crude simplifications of a real city – has proven to be largely verified by empirical data, as we will see below.

In the second part of the paper I will show how theoretical models developed by economists can identify potential conflicts between urban development strategies and the predictable functioning of labor and land markets.

Urban strategies that are in obvious conflict with economic reality have little chance of being implemented, and if implemented are extremely costly to a city's economy. Poorly conceived urban strategies are not just innocent utopias, they misdirect scarce urban investments toward locations where they are the least needed and, in doing so, greatly reduce the welfare of urban households. These failed strategies make housing less affordable and increase the time spent commuting.

THE QUANTITATIVE MODELS USED BY ECONOMISTS

Planners and urban economists do not have the same objectives. Planners aim at transforming existing cities. They like to speak about their plans in terms of "vision"[1]. The vision is often expressed with abstract non-measurable qualifying terms: "livable city," "resilient city," "sustainable city." An urban planner's vision can be achieved through design, regulations, and capital investments. Economists, by contrast, are content to play a less ambitious but more analytical role. They are mostly interested in understanding the way market forces and government action interacts in shaping cities. They love it when they discover a counterintuitive interaction between markets and land regulations, for instance. Economists attempt to identify

1 The formulation of a "vision" to guide urban development is expressly recommended as one of the eight steps required to design an Urban Development Strategy by the World Bank and the Cities Alliance, http://www.citiesalliance.org/sites/citiesalliance.org/files/CA_Docs/resources/cds/cds-guidelines/cds_guidelines_final.pdf causalities by analyzing empirical data. Economists, like other social scientists, specialize; most neglect the spatial dimension of the economy. Urban economists, though, focus specifically on spatial organization.

Economists develop theories and hypotheses that they represent with mathematical models that are usually based on extreme simplifications of the urban reality. However, the purpose of these models is to have both descriptive and predictive power. Economists test the relevance of their models by comparing the descriptive and predictive values they generate with empirical data collected in real cities.

Simplification is not necessarily a bad thing when we attempt to understand how something works. After all, the maps used by urban planners are also an extreme simplification of the real world. However, in spite of being a very simplified version of reality, maps' practical uses are not in doubt. A map at the scale of 1 to 1 would not be very useful. We should not reject a priori a theoretical construct because it rests on a model that is a crude simplification of a real and very complex city. The standard urban model described below is the necessary and appropriate starting point for understanding the way a city's spatial structure is shaped by land prices and how these prices emerge and evolve.

1. THE MONOCENTRIC MODEL OR STANDARD URBAN ECONOMICS MODEL

The monocentric-city model, or standard urban economics model, that was initially developed by Alonso (1964), Mills (1967), Muth (1969), and Wheaton (1974), is exceedingly simple, simplistic even. However, the monocentric model has turned out to be a robust guide or benchmark against which to compare the form of many large and complex cities, and economists therefore usually call it the standard urban model. I will use that term in the rest of this chapter.

The standard urban model provides the building blocks for more complex models, where some of the initial simplifying assumptions are relaxed. The more complex models, such as the "Regional Economy, Land Use and Transportation Model" (RELU-TRAN), developed by Alex Anas[2], require many more inputs than the monocentric model. Many of these inputs, in particular the spatial configuration of the main circulation network, are city-specific. As a consequence, these models provide more accurate results when some inputs change, as in the case of the RELU-TRAN model's calculations of projected commuting time and non-job related trips. However, because these more complex models require many city-specific inputs, using them makes it more difficult to draw general conclusions in the way markets influence shapes and densities in cities with different spatial configurations.

For this reason, in this chapter I will discuss only the use of the standard urban model. Strangely, not only is the simplest version of this model based on an extreme simplification of the spatial structure of real cities but its assumptions depart significantly from the way real cities are organized. In spite of its approximation of reality, the standard urban model has a strong descriptive and predictive power on the structure of most existing cities, including cities that are not monocentric at all, like Atlanta or Los Angeles.

The standard urban model is not a curious paradox limited to academic debates in specialized journals; planners can use it to solve practical everyday problems. For instance, I will show how a simple form of the model can be used to assess whether a city might be consuming an excessive amount of land at the expense of rural land, what the popular press would call "sprawl." The use of economic models should help clarify many issues concerning densities and land use that are too often approached in a more emotional than quantitative way.

By contrast, cities built without land markets -- as cities of the former Soviet Union were -- are the only ones for which the standard urban model has no descriptive and predictive power. However, as the model is explicitly built to reflect the effect of land markets on urban structures, this exception should not be unexpected. In addition, when cities that had developed during several decades under a command economy -- like the cities of Eastern Europe -- resume operating under market conditions, their structures tend to converge again toward the pattern predicted by the model[3].

The simplest version of the standard urban model is based on the following assumptions:

2 Anas, Alex, and Yu Liu,2007, "A Regional Economy, Land Use, and Transportation Model (RELU-TRAN©): Formulation, Algorithm Design, and Testing". Journal of Regional Science, Vol. 47, No. 3, 2007, Pp. 415-455

3 See "The Spatial Structures of Central and Eastern European cities: more European than Socialist?" International symposium on post-communist cities , University of Illinois at Urbana-Champaign June 2004 http://alainbertaud.com/wp-content/uploads/2013/08/AB_Central-European-Spatial-Structure_Figures_2.pdf

1. The city is located in a featureless plain where agricultural land has a uniform rent
2. All jobs are concentrated in a Central Business District (CBD)
3. People commute to work following an infinite number of straight radial roads

The reader will acknowledge that when I was talking about a gross simplification of real cities I was not exaggerating! The model aims at predicting the variations in land price and density (i.e. land consumption) when land users compete with each other and when their transport costs are proportional to the distance between their residence and the city center. However, planners and economists can also use the standard model to analyze a specific city because it is relatively easy to relax some of the assumptions to reflect ground reality. For instance, real road distances could be substituted for the "as the crow flies" distances assumed by the model. This is particularly useful when considering cities with unusual topography like Rio de Janeiro or Hong Kong.

The equations predicting land price and population density at a given distance from the CBD constitute the most useful properties of the standard urban model[4]. These equations show that rents, land prices and population density values will be the highest in the CBD and will fall as the distance from the center increases.

Urban land prices are driven by transport costs paid by users (direct cost of transport like transit fare, tolls or gasoline cost, plus the opportunity cost of the time spent traveling). Transport costs increase with distance from the city center. The trade-off made by land users between the cost of transport in different locations and their desire to consume land results in land prices decreasing as transport costs increase. Land users react to differences in land prices by consuming less land where land is expensive and more where it is cheaper. As a result, density decreases when the distance to the center increases. The negatively sloped density curve reflects the way households and firms use land more sparingly when its price increases

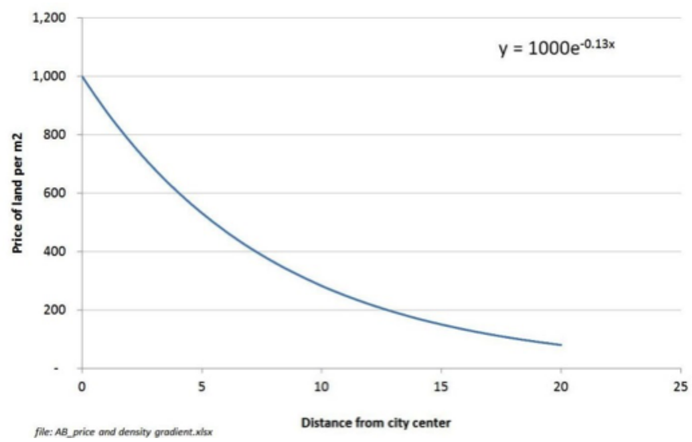


Figure 1: Profile of land price changes by distance from city center

closer to the city center. Land users are able to reduce their land consumption by building taller buildings where land is expensive close to the city center and less tall ones where land is cheap on the periphery. The declining price of land from the center to the periphery is responsible for the decrease in density as the distance to the center increases. Put another way, households and firms are compensated for their longer commute by being able to use more land and floor space.

It is important to realize that high land prices are causing high densities and not the other way around. I will expound upon the importance of the relationship of land prices --> density in the second part of this paper, which evaluates Hanoi's master plan.

The relationship between distance and land prices is expressed by the following equation:

Equation 1

$$P(x) = P_0 \, e^{-c\,x}$$

Where:

- P is price of land at distance x from the center of a city;
- P_0 is the price of land at the center;
- e is the base of natural logarithms;
- c is "the price gradient," or the rate at which land prices falls from the city center.

For instance, in a city where the price of land in the center is equal to 1000 units and decreases to 150 units at 15 km from the center, the price gradient would be 0.13. The price of land at a distance x from the center would decrease following the profile shown in Figure 1.

4 Readers not familiar with the standard urban model and curious to learn how these equations were derived could refer to Chapter 2 in Jan K. Bruekner's book: "Lectures on Urban Economics", MIT Press, 2011, and for a most complete discussion of the empirical data to Chapter 8 in Arthur O' Sullivan's " Urban Economics" Irwin, (1993) The equation that gives the variation of population densities by distance to the center is similar to equation 1:

Equation 2

$$D(x) = D_0 e^{-gx}$$

Where:

- D is the population density at distance x from the center of a city;
- D0 is the density at the center;
- e is the base of natural logarithms;
- g is "the density gradient," or the rate at which density falls from the city center.

The gradients c for price and g for density are the most important outputs of the model as they provide the rate at which the prices and densities change with distance from the city center. The more expensive the transport (in time) and money (relative to households' income), the steeper the gradient.

In a real city, we can easily calculate the existing density gradient by running a regression analysis on observed price or density points at various distances from the center (Figure 2). In annex 1 I describe the methodology I used to calculate densities at various distances from the center of real cities in the following examples.

The graphs in Figure 1 and Figure 2 show the average price or density by distance from the city center. However, in some cities there could be significant variations in price and density gradient depending on the direction along which the prices and densities are measured. For instance, in cities like Paris – where households' incomes are much higher in the western part than in the eastern part of the city – the gradient would be flatter on the west side than on the east side, as the gradient depends on the ratio between households income and transport costs. The same dissymmetry would be observed in Chicago for the north side vs. the south side of the city.

The profile of densities shown in Figure 2 will change over time as income and transport technology change. For instance, increase in households' income, decrease in cost, and increase in speed of transport would flatten the profile of both prices and densities. Inversely, an increase in population, everything else being equal, would increase both land prices and densities.

In many cities during the last fifty years, households' incomes have increased while transport technology has made commuting trips faster and cheaper. As a result, the gradients of land prices and densities have become flatter. The expected flattening in the density profile is such that urban economist Stephen Malpezzi claims that, "The monocentric model contains the seeds of its own destruction!" Why? Because as a city grows, as incomes rise, as transport costs fall, paradoxically what starts out as a monocentric city becomes polycentric, and the original "steep" price/rent/density gradients flatten inexorably. These are features and predictions built into the model.

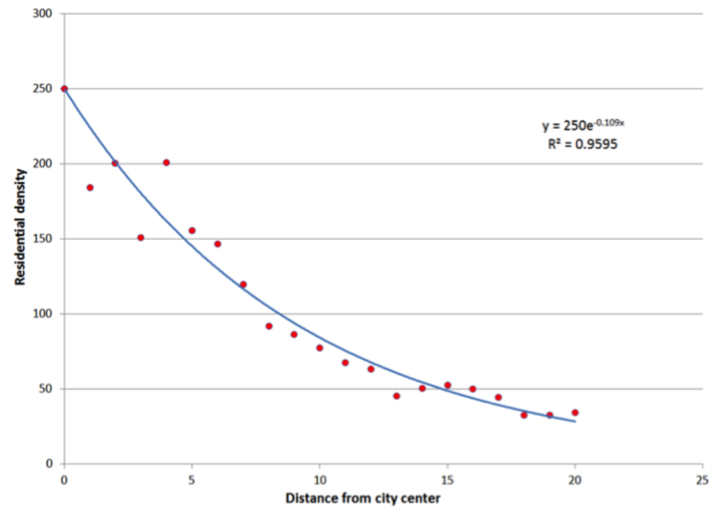


Figure 2: The calculation of the density gradient by using a regression, based on observed densities in a real city

DOES THE SPATIAL DISTRIBUTION OF LAND PRICES CORRESPOND TO AN OPTIMUM SPATIAL ORGANIZATION?

The economists that developed the standard urban model are not proposing it as an absolute optimum urban structure. They are only saying that, given transport costs, income, and total population, this is the way market forces will distribute prices and densities around a central point, providing the assumptions of the model are met. The objective of the model is to be descriptive and predictive. For instance, if transport costs decrease by x percent, with everything else staying constant, the city is likely to expand by y kilometers.

However, economists assume that if the utilities and production functions forming the base of the model were correct, then the welfare of households and firms would be optimized when the land prices and densities reach the equilibrium profile predicted by the model. Households and firms settling farther away from the center are being compensated for their higher transport costs with lower land prices.

The model assumes that if the land market is able to function without too many distortions, the profile of prices and densities will correspond to a distribution of land between users that will reflect the "best and higher use." There is therefore a hint of spatial optimization when subsidies, taxes, or regulations are not distorting land prices and transport costs. While these conditions are probably never met in the real world, the model tells which directions the prices and densities would be moving if the distortions were removed.

For instance, in countries where the price of gasoline is heavily subsidized, like in Egypt, Iran or Mexico, the standard model tells us right away that cities will extend much farther away from the center than in cities where the price of gasoline reflects market prices[5]. In these countries, it is useless for planners to try to devise regulatory barriers against "sprawl," it is only necessary to remove the subsidies on gasoline to get closer to an optimum equilibrium between distance and quantity of land consumed. The use of an abstract theoretical model can therefore suggest practical solutions in the real world in which planners are working.

The users of urban roads seldom pay market rents for the road area they occupy[6] while commuting; their transport cost is therefore subsidized by the amount of rent they are not paying for using roads. Users of the standard urban model can then infer that the subsidy in the use of road space increases the built-up area of the city by an area that can eventually be calculated. Pricing the use of roads through tolls could eventually restore land consumption to an optimum level. Using market mechanisms to improve land use efficiency would achieve better results than trying to design regulations to achieve the same results.

Because the model provides the profile of densities and prices under undistorted market conditions, it is possible to compare the current price and density profile of a city to what the model predicts and calculate the costs of the distortions. For instance, using the standard urban model, the economist Jan Brueckner and I calculated the unnecessary expansion in the city of Bangalore in India created by the poorly designed height regulations restrictions[7]. In another interesting practical application, Jan Brueckner applied the model to calculate the welfare gains obtained in dismantling apartheid policy in the cities of South Africa. He analyzed the changes in prices and land consumption when freedom of residential location is granted to all citizens and demonstrated that there has been a large aggregate welfare gain by eliminating the spatial distortion imposed by the apartheid land use regulations[8]. The results hold for all sorts of segregations imposed by land use regulations or discriminations of various types, income segregations being the most common.

In this paper I want to demonstrate that the model is a fairly good predictor of the spatial distribution of prices and densities when a city develops under not-too-distorted market conditions. And, as a corollary, that the model can be used both to test actual market distortions in existing cities and whether a planned spatial strategy contradicts the predictable pattern of land prices and densities set by markets. I will use the Hanoi master plan case study to illustrate this example in the operational use of the standard model.

How does the standard urban model fit real cities?

The standard urban model claims to be both descriptive and predictive. To determine the operational usefulness of the model it is therefore necessary, first, to verify how accurately its equations describe the variations in densities and land prices in existing cities; and second, whether changes in density patterns and price follow the predictions of the model when variables like income, transport costs, and population size change.

TESTING THE DESCRIPTIVE QUALITY OF THE MODEL

Testing the accuracy of the standard urban model on real

5 The taxpayer that pays the gasoline subsidy pays the price for the misallocation of resource.

6 One of the few exceptions might be in Singapore where the tolls for using central city roads are constantly adjusted to reflect the equilibrium between supply and demand.

7 "Analyzing building-height restrictions: predicted impacts and welfare costs" Alain Bertaud and Jan K. Brueckner ,Regional Science and Urban Economics (2005)

8 Brueckner, Jan (1996) "Welfare Gains From Removing Land-Use Distortions: An Analysis Of Urban Change In Post-Apartheid South Africa" Journal of Regional Science, Volume 36, Issue 1, pages 91–109, 1996

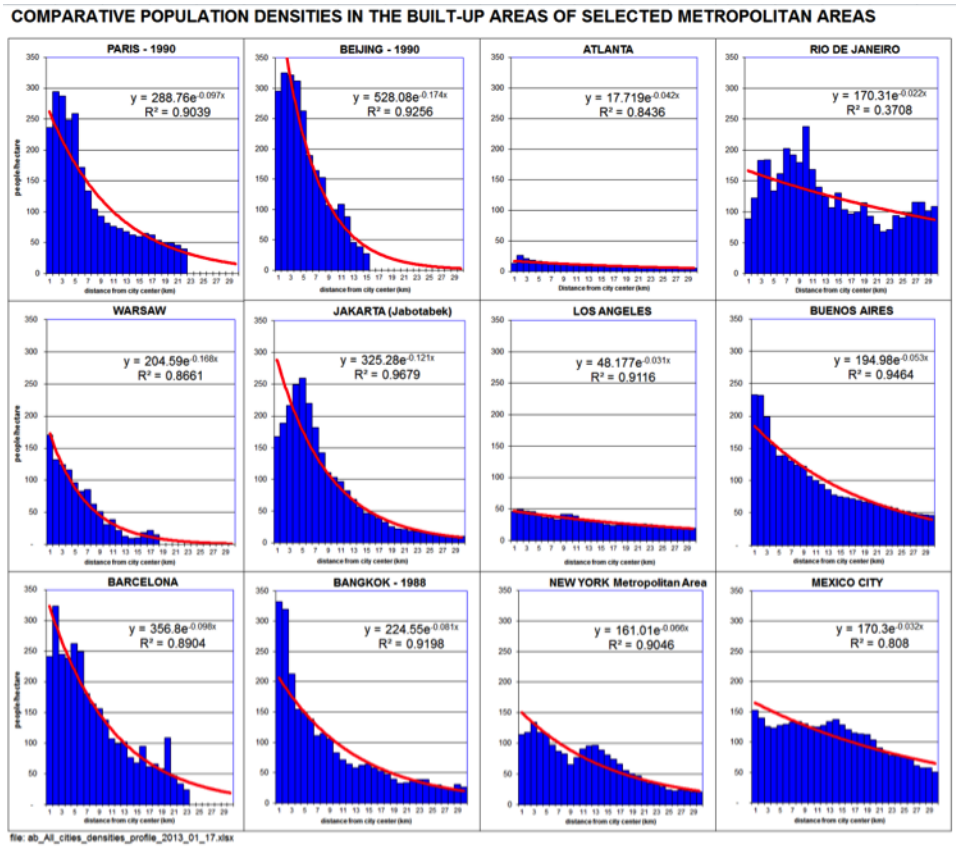


Figure 3: The calculation of the density gradient by using a regression, based on observed densities in a real city

cities is relatively easy, though time consuming[9]. Densities by neighborhood are easier to calculate than prices; the prices of land transactions are not always accurately recorded. With my colleague Stephen Malpezzi, I have calculated population densities by intervals of one kilometer from the city center for about 50 metropolitan areas around the world[10].

Figure 3 shows density profiles from a sample of 12 cities in Asia, Europe and North and South America. The graphs show horizontally the distance from the city center from 0 to 30 kilometers, and vertically the variations in built-up densities from 0 to 350 people per hectare. The bars on the graph show the measured density within each annulus located at one-kilometer intervals from 1 to 30 kilometers from the city. I obtained the average density by dividing the population of the portion of census tracts in each annulus by the total built-up area within the annulus. The use of GIS software makes this operation not quite as cumbersome as it sounds!

The cities selected have widely different cultures, histories, economies, climates, and topographies. None of these cities meets the strictly monocentric criteria specified by the model. Some have a dense center with a high job concentration, like Paris, New York and Barcelona. Others have extremely dispersed job locations, like Atlanta and Los Angeles. Most others are in between.

How well do the density profiles of the 12 cities in Figure 3 fit the predictions of the standard urban model? The model predicts that the population density of a city will decrease from a central point toward the periphery following a negatively sloped exponential curve. The profiles of observed densities for the 12 cities fit an exponential density curve as predicted by the model. The fit between the actual density profile and the model exponential curve (represented by a red line on the graphs of Figure 3) is striking. Table 1 shows the R square[11] (R2) value representing the similarities between the observed density value

9 The full method used to calculate population densities by interval distance is described in the technical annex of this book.

10 See Bertaud and Malpezzi , 2007, "The Spatial Distribution of Population in 52 World Cities: Recurrent Patterns and Some Implications for Public Policy" , working paper University of Wisconsin

11 R2 is a statistical measure of goodness of fit i.e. how close are observed values from the values predicted by a mathematical model. The range of possible values for R2 vary from a minimum of 0 , implying no fit at all, to a maximum of 1 indicating perfect fit.

City	gradient	R^2
Beijing	-0.174	0.92
Warsaw	-0.168	0.86
Jakarta	-0.121	0.97
Barcelona	-0.098	0.89
Paris	-0.097	0.90
Bangkok	-0.081	0.92
New York	-0.066	0.90
Buenos Aires	-0.053	0.95
Atlanta	-0.042	0.84
Mexico City	-0.032	0.81
Los Angeles	-0.031	0.91
Rio de Janeiro	-0.022	0.37

Table 1 : density gradient of 12 cities

at each kilometer interval and the exponential curve predicted by the model. With the exception of Rio de Janeiro, all R2 values are above 0.8, seven out of twelve are above 0.9!

Why is Rio de Janeiro the only city in my sample of twelve with a significant but mediocre fit, with a R2 equal to 0.37? Rio has a beautiful but complex topography with numerous ocean inlets and steep rocky hills fragmenting the built-up area. The model assumption that all distances are counted along radial roads converging on the city center is a good enough approximation for cities like Beijing, Buenos Aires, or Paris, which are built in a flat plain. However, the approximation is not good enough for cities like Rio de Janeiro, in which topography constitutes a barrier to direct access that lengthens some distances and not others. The radial roads assumption of the model could easily be relaxed for cities with difficult topography by replacing radial distance by real distance measured on the existing road network. The graph of Figure 3 that shows the density profile of Rio de Janeiro could then be redrawn to represent real travel distances from the center, following existing roads rather than imaginary radials. If this were done, the fit would probably be better.

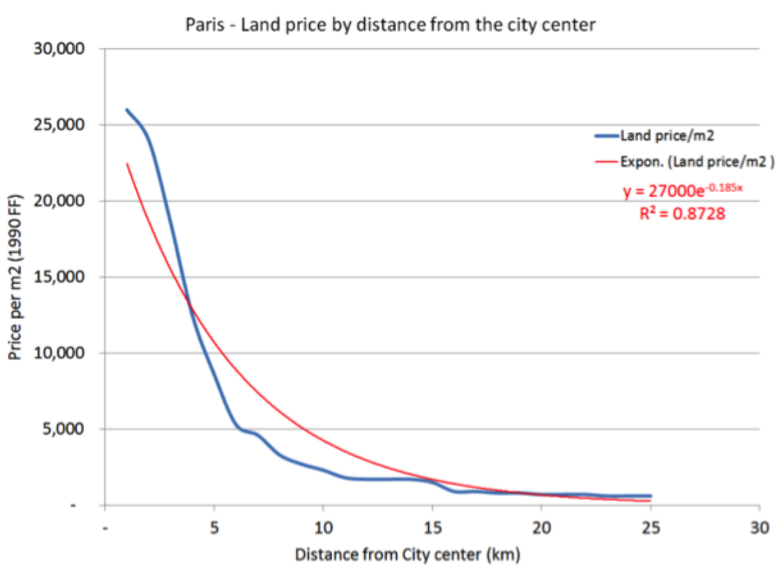


Figure 4: profile of land prices in Paris, 1990

Reliable spatial data on land prices or rents is more difficult to collect than it is for densities. There are some difficulties in finding reliable transaction data in cities of developing countries where a large portion of land transactions are informal and where even formal transactions are often underreported because of high taxes on title transfers. However, a vast amount of literature covers the changes in land prices by distance from the city center in OECD cities for which reliable data is available. Figure 4 shows the land price profile for Paris by distance from the city center (Hotel de Ville). The fit between observed prices and the expected exponential curve predicted by the model (R2=0.87) is quite good. Some studies, using historical data prices[12], show that the price gradient moves in directions predicted by the standard urban model when income increases and the cost of transport decreases. One problem is that in very large cities it is sometimes difficult to agree on what constitutes the center of the city. For instance, the study on historical prices in New York uses City Hall at the central point of reference, while a much more recent study conducted by Andrew Haughwout for the entire New York Metropolitan area in 2008[13] used the Empire State Building as the city center.

We can learn a lesson from the density profiles of Figure 3 and Paris' price profile in Figure 4. Densities and land prices are not produced by "design" but by market forces. A planner thinking that a city would be improved by having higher densities should therefore advocate higher land prices. More expensive or slower transport would increase the desirability of neighborhoods closer to the city center and therefore increase their land prices, everything else being equal.

The advocates of "compact cities" should realize that a compact

12 Jeremy Atack, Robert A. Margo 1998, "Location, Location, Location!" The Price Gradient for Vacant Urban Land: New York, 1835 to 1900", The Journal of Real Estate Finance and Economics, March 1998, Volume 16, Issue 2, pp. 151-172

13 Haughwout, Andrew and James Orr, and David Bedroll, 2008 "The Price of Land in the New York Metropolitan Area" Volume 14, Number 3 April/May 2008 ,Federal Reserve Bank of New York

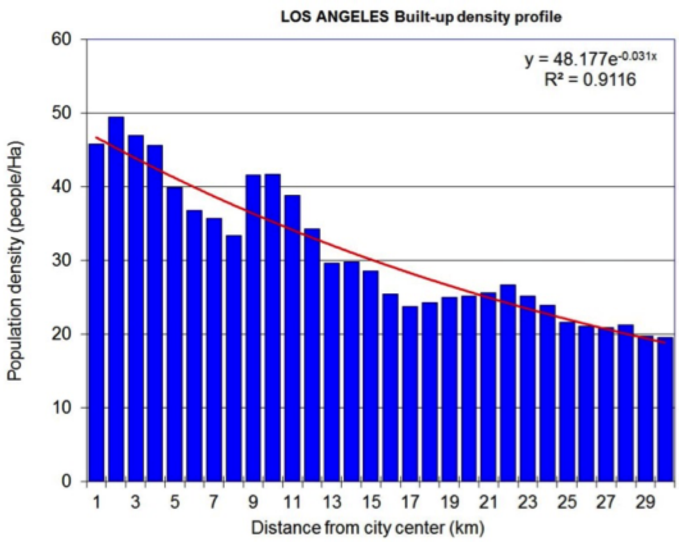


Figure 5: density profile of Los Angeles

city – defined as a city that uses less land for sheltering the same number of people as another city – has a price. This price will not be paid by the urban planner advocating it but by the households and firms who will live in that compact city. Planners advocating a "compact city" strategy, however, think that it will happen by just assigning densities for different city locations on a master plan.

I am not exaggerating here, many master plans "design" densities the way an architect may decide the color of a building. In the last part of this paper I will show a concrete example of arbitrarily planned densities – Hanoi's master plan – and the problems it causes.

WHY DOES THE MODEL SEEM TO FIT OBVIOUS POLYCENTRIC CITIES LIKE LOS ANGELES?

Why should the model seem to apply equally well to monocentric cities and to acentric cities like Los Angeles and Atlanta, which have only a weak concentration of employment in their CBD? Figure 5 shows the same population density profile of Los Angeles as Figure 3, just at a larger scale. The highest density is only 50 people per hectare in the center. At 30 kilometers from the center, it drops by 60 percent to about 20 people per hectare. Los Angeles' decrease in density is small compared to Bangkok, for instance, where densities drop by 93 percent at the same distance from the center. However, with a R2= 0.91, the profile of density follows the prediction of the model in spite of the fact that it does not meet the initial assumption that all jobs are concentrated in the CBD. Los Angeles's CBD, which is roughly located at the centroid of the metropolitan built-up area, contains only a small percentage of jobs compared to the rest of the metropolitan region (about 11% of all the jobs in LA according to O'Sullivan[14]). Let us try to find out why the distribution of densities should be consistent with the one predicted by the standard urban model.

Let us consider an imaginary circular city with a radius of 12 kilometers where jobs are uniformly distributed within the built-up area (Figure 6). I will call this type of city "acentric" to distinguish it from the monocentric and polycentric types of spatial organization, where jobs are concentrated in one or several locations. In an acentric city jobs are evenly distributed within the built-up area. This is roughly similar to the

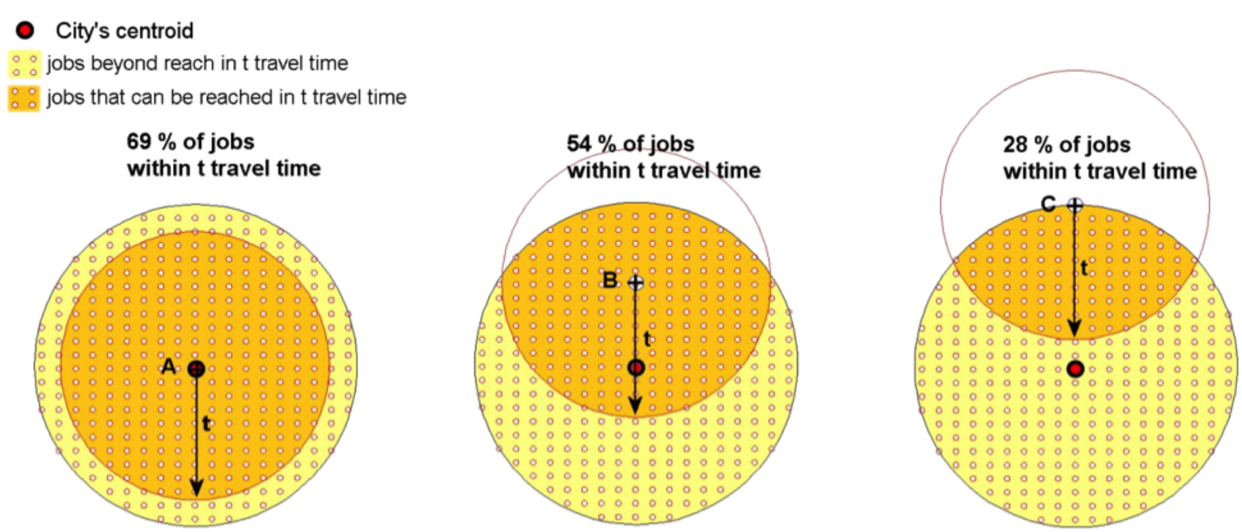


Figure 6: schematic representation of access to labor market in a city with uniform distribution of job locations

14 *Arthur O' Sullivan "Urban Economics" page 282*

distribution of jobs in Los Angeles. Because, by definition, the acentric city doesn't have any area with a high job concentration, it doesn't have a CBD. But it has a centroid. The centroid is the point from where the sum of the distances to all other locations within the shape is the shortest.

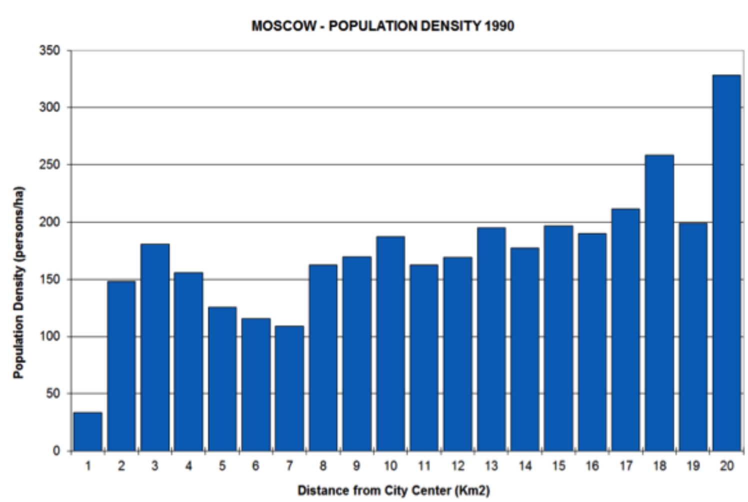
Let us consider three workers who are living at different locations A, B, and C, and let us measure how many jobs they could potentially access within an arbitrarily fixed travel time of 30 minutes at an average travel speed of 20 kilometers/hour corresponding to a circle of 10km radius. For simplicities' sake I will assume that the travel time is the same for all three workers in all directions. Below or within 30 minutes travel time, each of the three workers would be able to reach any job located within an area corresponding to a circle with a 10 km radius. While the area that can be reached in 30 minutes is the same for all three workers, the number of jobs located within the 30-minute travel range would be different depending on the location of their dwelling within the city.

Let's examine the worker residing at point A, located at the centroid of the city shape (left graph of Figure 6). Traveling 30 minutes from A, this worker can reach 69% of the built-up area in 30 minutes (the ratio between the 10km radius circle accessible in 30 minutes and the entire area of the city). This worker can therefore access 69% of all the jobs locations in the city, as our hypothesis was that job locations were evenly distributed within the built-up area.

The second worker is located at point B (middle graph in Figure 6), which is 6 kilometers from the built-up area's centroid or halfway between the city center and the edge of the built-up area. He will have access to only 54% of jobs, as the area he can reach by traveling 30 minutes does not completely overlap with the city's built-up area where the jobs are located.

The third worker is located in C, at the edge of the built-up area (right hand graph in Figure 6). She will be able to reach only 28% of the built-up area and therefore only 28% of the jobs in the city. If worker C wants to reach the same number of jobs as, say, worker A, she could do it by traveling longer than 30 minutes. From this schematic graphic example we can see that, even in an acentric city where jobs are evenly distributed within a city, the advantage of a central location still exists in terms of access to the labor market and to amenities. Although jobs and amenities are uniformly distributed within the built-up area, a household located close to the center of the urban shape (it does not need to be a central business district) has access to more jobs and amenities than a household located at the periphery within the same travel time. This locational advantage would generate more demand for more centrally located housing and it explains the existence of a density gradient with densities decreasing outward from the centroid of the urban shape, as we have seen in the density profile of Los Angeles in Figure 5.

The accessibility advantage of a centrally-located household is not as strong in an acentric city as it would be in a monocentric one, but it is still significant. If the hypothesis represented by Figure 6 is correct, we would expect acentric cities with a uniform or quasi-uniform job distribution to have a density gradient that still shows a decrease in densities with distance from the centroid of the built-up area, even in the absence of an identifiable CBD. Obviously, an acentric city would have a lower density gradient than cities that have retained a dominant CBD, like Beijing, Barcelona and Paris. The value of Los Angeles' density gradient (Table 1) is only about 1/6 of Beijing's and about 1/3 of the gradient of Barcelona and Paris, which is consistent with our hypothesis on acentric cities. The small sample presented in Table 1 does not constitute irrefutable proof that the value of population density gradients decreases when job dispersion increases in a metropolitan area, but it shows that the standard



Source: Author calculations, based on 1990 census data and land use maps

Figure 7: Moscow density profile 1990

urban model remains relevant for cities that are either polycentric or acentric.

WHY A FEW CITIES DO NOT FIT THE MODEL AT ALL AND WHY IT REINFORCES THE MODEL'S CREDIBILITY

Empirical evidence shows that the standard urban model's negatively sloped exponential curve can aptly represent population density variations in most monocentric, polycentric, and acentric cities. However, if the use of the standard urban model were limited to a description of existing density patterns in cities, it would be of little use to planners. Existing densities are relatively easy to measure, as seen above, and there would be no need for a model. The model is important because it can predict what would happen to densities and land prices when the values of some market variables change over time. Because I put so much confidence in the predictive power of the model, it is necessary at this point to explain why some cities' density profiles do not fit the negatively sloped density profile and why cities with completely dispersed job locations fit the predictions of the model very well.

Among the 53 cities for which I collected data, a few do not fit the model at all. For instance, the graph in Figure 7 shows the density profile of Moscow, calculated in 1990 before market reforms were introduced to the city. The standard urban model does not accurately describe the densities of Moscow (1990), Brasilia (2000), and Johannesburg (1990)[15], for example. Not only do the densities not decrease exponentially from the city center, they sometimes also increase or follow a U profile. However, these exceptions should not surprise us. After all, the main claim of the model is that it reflects the spatial structure self-generated by free land markets. Planners and engineers designed these cities within a political system that allowed them to ignore land prices.

The absence of market generates alternative forms to the one predicted by the standard urban model. This is not surprising; supply and demand forces, which are absent in a command economy, shape the urban structures predicted by the model.

The predictive capability of economic models is important for operational urban planning

Economic models, in spite of their theoretical simplifications, are most useful for their predictive capability. The operational value of economic models rests in their ability to forecast general directions in land and housing price levels and in densities when income, land supply, transport cost, and transport speed change. Economic models cannot provide accurate projections of densities in specific areas of the city, but they are useful to anticipate the general direction of relative price and densities. One of the main lessons to be learned from the use of economic models is that variations in densities and land price are usually predictable and caused by variations in households' and firms' income, transport costs, and by the elasticity of a city's land supply.

Land and housing prices and densities obey the basic demand and supply mechanism. The high land values created at the center of large cities decrease with distance in the same way the force of gravity of a large planet diminishes with distance from this planet. Planning future land use while ignoring the predictable land value based on location makes no more sense than trying to ignore gravity when designing an airplane. The real world example of Hanoi's master plan, provided below, will illustrate a typical case of planners trying to "design" densities, therefore implicitly "designing" land values instead of basing their plans on the projection of predictable land values and densities created by predictable variations in income and transport costs.

FALL OF DENSITIES OVER TIME

The standard urban model predicts that the population density gradient will fall in absolute value as urban incomes rise, the population grows, and transport costs fall. Shlomo Angel observed this flattening of the density curve across a large number of modern cities[16] he surveyed. Angel explores in detail the historical evolution of densities in world cities. He provides historical data for 30 large cities in all 5 continents, showing the evolution of built-up densities between 1800 and 2000. His data shows that, while densities in these cities often peaked around 1900, densities have since significantly declined in all of them, mostly due to increase in income, decrease in transport cost, and progress in transport technology. Another set of data analyzed by

15 For a discussion of cities developed without land markets in command economies see "Socialist Cities without Land Markets", by Alain Bertaud and Bertrand Renaud, Journal of Urban Economics, 1997, 41, (1), 137-151

16 Shlomo Angel, "A Planet of Cities", Lincoln Institute, 2012

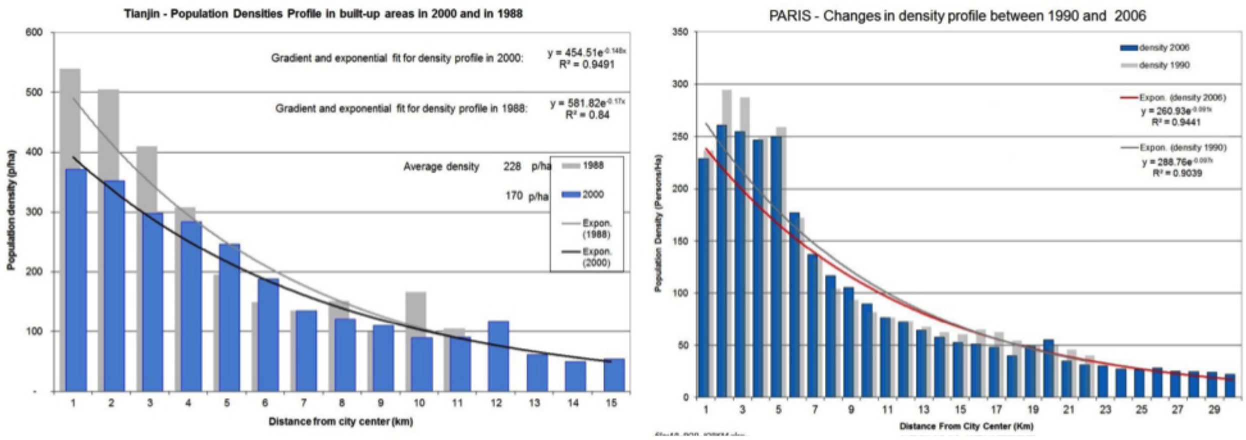


Figure 8: change over time in the density gradient in Paris and Tianjin

Angel shows the density changes in 120 world cities between 1990 and 2000. The data shows that densities have increased in only 16 of the 120 cities, all in developing countries. All of the others showed a decline in built-up densities. Angel points-out that the decrease in built-up densities was strongly correlated with rising households' income and decreasing transport costs in proportion to income, which is consistent with the standard urban model predictions. Angel's exhaustive urban density database therefore seems to confirm the predictive quality of the model.

While average densities tend to fall when income and transport costs decrease, how do neighborhood densities change within an urban area under the same conditions? The standard urban model forecasts a decrease in the value of the density gradient; or expressed differently, the profile of densities becoming flatter over time with densities in the center decreasing and densities in the periphery increasing slightly. Figure 8 shows the variations in built-up densities in Tianjin between 1988 and 2000 and in Paris between 1990 and 2006. While the history and the economic bases of the two cities have very little in common, the increase in household income and decrease in transport costs relative to income produced the same spatial transformation. Tianjin's density gradient decreased by 1.1 percent per year while Paris' gradient decreased by a more modest 0.4 percent per year. This difference in density gradient decrease is consistent with the faster increase in households' income in Tianjin compared to Paris.

The change in density profile is relatively slow in both cities. Even the faster change in Tianjin is still modest in light of the massive economic and construction boom that took place in Tianjin between 1988 and 2000. Urban structures are very resilient and change slowly. The direction of the change in density profile in both Tianjin and Paris is consistent with the predictions of the standard urban model.

REGULATIONS THAT DISTORT LAND PRICES

Regulations may decrease the total area of floor space that can be built on a given area of land. These types of regulations would of course change the price and density profile that the standard urban model would project under unconstrained markets. For instance, regulations routinely restrict the heights of buildings or impose a maximum limit on the number of dwelling units that can be built per hectare. If these regulations are binding, i.e. if

Figure 9: sale price and rent of very small apartments in Paris in 2014

the regulations reduce the number of dwellings that developers have built to respond to consumers' preference for these areas, then the regulations will create a shortage of floor space in areas of high demand. As a result of this shortage the price of floor space will increase compared to what it would have been without the regulations. In turn, the increase in price might result in higher densities as some consumers might decide to use less floor space in order to be able to afford this expensive but desirable location.

The limitation on building height imposed by the municipality of Paris illustrates this point. There is a high demand for living in the center of Paris because of its high level of amenities and because of its high concentration of jobs. Because of the limitation on the supply of floor space imposed by the height limitation, the size of apartments decrease and their price increases. The real estate posting in Figure 9 shows the very high prices of tiny rooms, between 9 and 11 square meters, whether for rent or for sale. The absence of elevators in some historical buildings helps to lower the price of apartments, which is the case for the 11 square meter studio whose advertisement is shown on the left of Figure 9.

I am not suggesting here that the municipality should necessarily amend its building height restrictions within the city central core. The regulations' aesthetic objective is achieved; it perfectly preserves the historical skyline of Paris. However, many in Paris lament the extremely high housing prices and the exiguity of apartments. High prices and low housing floor consumption are the direct consequence of preserving historical Paris. If the heights restrictions were widely relaxed, it would increase the supply of residential floor space and lower housing prices, but by removing one of the chief attractions of Paris, it might also decrease the demand for a central location that would have a lower aesthetic quality.

In cities other than Paris, most regulatory constraints on floor area ratio aim at "controlling" densities and therefore creating an artificial shortage of floor space or developed land. Consequently, these regulations usually increase densities – the opposite of the desired result. Mumbai, where planners attempted to reduce densities by limiting the floor area ratio in a draconian fashion, has, as a result, one of the highest average built-up densities in the world[17].

The same is true for regulations aimed at increasing densities. In the absence of consumer demand, planners cannot increase densities by regulatory fiat. Regulations that limit the number of dwellings per hectare, for instance, are an attempt to "design" densities through the proxy of regulations.

There is nothing wrong with planners attempting to project the number of dwellings per hectare that the market is likely to supply in a given neighborhood. But to attempt to transform that guess into a regulation is both detrimental and delusional.

2. "SPRAWL": THE STANDARD MODEL AND THE EXPANSION OF CITIES

Models developed by urban economists help to understand how land markets shape cities. We have seen that land markets – not planners' designs – generate densities. Densities are indicators of land consumption[18]. If markets generate densities, then they also define how much total land a city will consume and, by extension, the limits between urban and rural land. As I will show below, the standard urban model explains how and why markets, whether distorted or not, establish this limit.

The expansion of cities into the countryside, often called "sprawl" when this expansion is considered wasteful, is probably one the most emotional urban issues discussed by the popular press and by advocacy groups. A Google search for the word "sprawl"[19] returns 5.9 million entries!

The concern about the ever-expanding limits of cities is at the core of the popular advocacy for "smart growth" and for "sustainable cities", which ask for the forceful containment of cities' expansion. Many urban critics and planners argue that unregulated cities expand too far into the countryside, causing increased commuting distances and dangerously decreasing the

17 Bertaud, Alain, 2011, "Mumbai FAR/FSI conundrum: the four factors restricting the construction of new floor space in Mumbai" http://alainbertaud.com/wp-content/uploads/2013/06/AB-Mumbai-FSI-Conundrun-Revised_June-2013_kk-ab1.pdf

18 A density of, say, 50 people per hectare is equivalent to a land consumption of 200 m2 per person (one hectare= 10,000 m2, 10,000/50=200)

19 Merriam Webster dictionary define sprawl as "to spread or develop irregularly or ungracefully" and follows by an example: "the city sprawls without apparent logic or plan to the west, north, and south — American Guide Series: Rhode Island".

Tianjin - increase in population and in built-up area between 1988 and 2000 within the 3 rd ring road

Year	Population	Built-up Area km2	density (people/ha)	Area of built-up land per person (m2)	Increase in population	Increase in built up area	increase in land consumption per person
1988	3,499,718	153.72	228	44			
2000	4,264,577	250.74	170	59	22%	63%	34%

Table 2: Tianjin - increase in population and built-up area between 1988 and 2000 within the 3rd ring road

amount of land devoted to agriculture. These critics call "sprawl" what they judge as excessive urban expansion at what they think are too low densities.

Presumably there is some population density threshold above which a city's development is "non-sprawl" and below which development is "sprawl." However, the anti-sprawl advocates clamoring for more "compact cities" have not yet defined this population density threshold. Opponents of "sprawl" puzzlingly use the term to describe both American cities like Atlanta and Chinese cities like Tianjin, which have densities of 6 and 170 people per hectare, respectively. At what density would the critics of sprawl say a city is using land reasonably?

Even the World Bank, in 2014, has recently joined the anti-sprawl chorus in its report on urbanization in China by titling a map of the Shanghai-Suzhou-Changzhou conurbation "Sprawl in Shanghai Metropolitan Region between 2000 and 2010"[20]. The map just shows the urban expansion that had occurred in this highly economically successful metropolitan region over ten years. No data presented in the World Bank report constitutes proof that the urban expansion shown on the map is either wasteful or inefficient. Given the large increases in this area's population and household income that occurred during this period, certainly some land expansion would be expected and not troubling. How can we know if land use is efficient? The standard urban model could provide us with a more rational and less emotional assessment of the matter.

THE CONCERN FOR THE LOSS OF AGRICULTURAL LAND

Often cities must expand into valuable agricultural land, which might appear to be a zero sum game between the area devoted to agriculture and the area occupied by cities. Because the reduction of agricultural area is linked in peoples' mind to a loss in food production, it is understandingly an emotional issue. In reality, food production increases and decreases have more to do with changes in land productivity and climatic variations than the area under nominal cultivation. But given the historical famines that plagued South and East Asia as recently as the twentieth century[21], it is quite understandable that a possible decrease in agricultural land raises concern.

The Chinese government, alarmed by the fast pace of urban expansion, has set urban land development quotas that severely restrict the conversion of agricultural land into urban land. The National Plan on New Urbanization (2014-2020), published by the Government of China to guide urbanization until 2020, prescribes a minimum density of 100 people per hectare for every new urban settlement in order to preserve agricultural land. In addition, the use of costly conversion quotas are required for any urban expansion requiring loss of cultivated land.

Many observers of rapid urbanization in Asia are alarmed by the fact that cities' land coverage expands at a faster pace than the urban population. As I was advising on the development of Tianjin in 2007, the city's managers were alarmed that Tianjin's land area was developing at a faster pace than its population (Table 2). Over a 12-year period the population of Tianjin had increased by 22 percent while the built-up area had increased by 63 percent.

The standard urban model has shown that densities will decrease when urban household incomes increase while urban transportation costs decrease in proportion to income. This change in density is easy to explain without using the model's

20 World Bank : "China's Next Transformation: Making Urbanization Efficient, Inclusive, and Sustainable" ,2014 , Supporting Report 2, "Planning and Connecting Cities for Greater Diversity and Livability" map2.2 page 143

21 It should be noted the most damaging famines of Asia, in Bengal in 1943 and in China during the Great Leap Forward in 1961, were caused by government policy and subsequent inaction and had nothing to do with a decrease in agricultural land area.

equation. As incomes increase, households wish to consume more floor space. Firms, originally operating dense sweatshops, acquire more land to provide more working space for their employees and for the more sophisticated machinery they operate; roads become wider to accommodate the increasingly intense flow of traffic. All these factors imply more land consumption per capita. Therefore, a decreasing density during economic expansion is not necessarily an indicator of wasteful land consumption. It all depends on household and firm income, the cost and speed of transport, and the rent of agricultural land during the period. Expecting that cities expand at the same densities as their core implies that densities should be uniform from the core to the periphery and that densities had been optimal since the city's foundation.

The standard urban model tells us that densities will decline as household incomes increase and transport technology improves. This is not a sign of inefficiency but a rational reallocation of inputs. As most of the new land development occurs on the periphery, it is normal that the density of newly developed land will be lower than the city average.

Low density at the edge of urban development is a normal and rational component of development, as it represents a maximization of utility for firms and households when market prices are not distorted. However, it is important to have a yardstick to measure objectively whether land developed at the fringe of cities has an inefficiently low density or not.

The anti-sprawl movement, while being vocal, does not represent a unanimous opinion. Some planners and many economists, like Peter Gordon and Harry Richardson, have argued that an elastic land supply is indispensable to maintaining affordable housing prices as a city's population and income rise. This is also one of the main arguments developed by my colleague Shlomo Angel in his book "A Planet of Cities," already mentioned earlier. Robert Bruegmann, in his book aptly titled "Sprawl," puts the question of cities' extension in context and debunks many of the "urban legends" that are an unfortunate feature of the discourse on cities and that typecast cities as voracious land consumers.

In the following paragraphs I will try to summarize what we have learned from the numerous theoretical and empirical papers

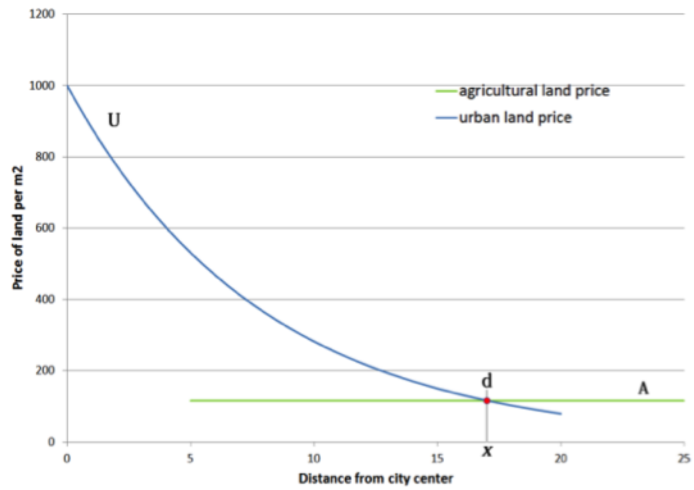


Figure 10: price of urban land and agricultural land define the limit of urbanization

written by Jan K. Brueckner, Steve Malpezzi and Kurt Paulsen, among many others. The work of these economists demonstrates that there is nothing idiosyncratic about how much that land cities occupy, where the limit of urbanization is located, and what the main variables on which this limit depends are. The theoretical concepts described in all these papers have been tested in US and European cities and also, in the case of Jan Brueckner' s paper, in 24 cities in Latin America, Africa and Asia[22]. The area occupied by cities and the locations of the built-up boundary depend on the relative value of three ratios: rural to urban income, the commuting cost to urban income, and agricultural land rent to urban rent. The land area used by cities, whether sprawled or compact, has very little to do with greedy developers, rapacious landowners, or irresponsible car-happy commuters.

My goal is not to review, comment, or paraphrase the work of these urban economists but to explain how planners can utilize their work to better understand how cities use land when their population increases and what economic and population variables are responsible for setting densities. In the next paragraphs, I will focus on what the standard urban model can teach us about the limits of urbanization and, by extension, what determines the area of cities.

The standard model helps to understand how far a city expands and why

Urban land prices decrease as distance from the city center

22 Brueckner, Jan K. 1990, "Analyzing Third World Urbanization: A Model with Empirical Evidence", Economic Development and Cultural Change, University of Chicago, 0013-0079/90/3803-0036

increases, reflecting the decreasing utility of land to the consumer, whether firm or household, due to increasing transportation costs. The graph in Figure 10 shows the curve U representing the variations of land price of an imaginary city as distance from the center increases. The line A represents the price of agricultural land at the periphery of this city. It is assumed that that this price does not vary with distance and represents the capitalized rent that farmers obtain from their crops. The more fertile and productive the soil, the higher the price of agricultural land would be[23]. The urban land price curve U intersects the horizontal line A representing the price of agricultural land at a point d at a distance x from the city center. The outer limit of built-up area of the city will be located at a distance x. At a distance shorter than x, developers will be able to outbid the agricultural price that farmers could otherwise get, enticing them to sell their land. Therefore, at a distance shorter than x, land will be converted from agricultural to urban use. Beyond the distance x, developers can only offer a price lower than the agricultural price of land. Farmers will therefore be unlikely to sell their land and the land will remain under agricultural use. The higher the price of agricultural land, the shorter the radius of urbanization x, everything else being equal. This has an important, interesting implication about the way cities expand. For a given population, a city's land prices and densities will be higher if it expands in highly priced agricultural land.

This is rather straightforward. Setting the limit of urbanization does not require conspiracy theories involving greedy developers in cahoots with devious car manufacturers, as one of the most persistent urban legends would have it[24].

We can see, if we accept the firms' and households' utility function implicit in the model, that the areas and densities of cities (implicit in the location of x), have no normative "good practice" value but are dependent upon the price of urban land at the fringe of urbanization compared to the price of agricultural land. Cities expanding into very productive agricultural land would have a smaller footprint, and therefore a higher density, than cities expanding in a desert, everything else being equal. Imposing a minimum normative density, such as the 100 people/ha in China, may result in resource misallocation. This density might be too low for cities expanding into valuable agricultural land, while it might be too high for cities expanding into land with little alternative uses like desert or mud flats.

THE URBAN-RURAL BOUNDARY WHEN THE PRICE OF AGRICULTURAL LAND IS DISTORTED

The point **d** on Figure 10, showing the limit of urbanization, is at the distance x where the price of urban land equals the price of agricultural land. If neither of these prices are distorted, this distance, and by extension the entire built-up area of the city, could be considered optimal. In other words, this distance and built-up area would maximize the utility of urban dwellers and firms as well as the farmers cultivating land at the edge of cities. However, if one or both prices were distorted, the point d would no longer represent the optimal limit of urbanization. For instance, let us look at the consequence on the urbanization limit, and therefore on a city's land consumption, when the acquisition price of agricultural land is undervalued compared to its real market value when based on agricultural productivity (Figure 11).

Let us suppose that the acquisition price of agricultural land (line A1) is lower than its real implicit market value (Line A2). This distortion in the price of agricultural land could be caused by a government using eminent domain to expropriate land occupied by farmers and paying a lower price than what they would obtain on a free market where the agricultural land price had been based on the capitalization of the rent produced by the land. This type

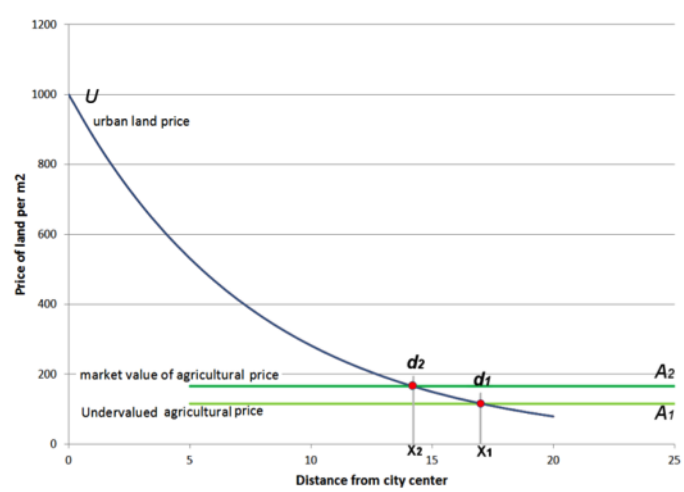


Figure 11: limit of urbanization when agricultural land prices are distorted

23 *I have assumed a uniform agricultural productivity in space and therefore A is a horizontal line.*

24 *See among others http://en.wikipedia.org/wiki/General_Motors_streetcar_conspiracy*

of expropriation happens often at the fringe of cities in China or in India[25] where governments use an administrative price usually lower than the market price for compensating farmers for expropriated land.

The graph in Figure 11 illustrates this situation. The price of urban land becomes equal to the undervalued price of agricultural land at point d1 at a distance x1 from the center. However, if the market price of agricultural land had been used, then the limit of urbanization will have been in d2 where the urban land price crosses the line A2 at a distance x2 from the city center. We can see that x1, the limit of urbanization with an undervalued agricultural price, is significantly farther away than x2. Undervaluing the price of agricultural land would therefore contribute to an overconsumption of land by urban users at the expense of agricultural land and therefore a misallocation of resources.

PRICES DISTORTIONS MAY CAUSE AN OVER- OR UNDER-CONSUMPTION OF URBAN LAND

The use of the standard urban model is unlikely to allow us to calculate the exact distance corresponding to an undistorted agricultural price. However, it does allow us to be certain that an undervaluation of the price of agricultural land will lead to an overconsumption of urban land. People concerned about the potential loss of agricultural land caused by urbanization can use the standard urban model to identify distortions that will eventually lead to the overconsumption of urban land. The use of the model points to the obvious solution to reduce land consumption to a more optimal level. The solution is for developers to pay a market price for agricultural land. The alternative solution, drawing a regulatory “urban growth boundary”[26] or a green belt at distance x2 to prevent further urban extension, will not work for two reasons. First, the model is not accurate enough to calculate the x2 distance. Second, if it was possible

25 In China, the discontentment of farmers with the price given by local government for their land create numerous protests, while in India in 2006, the government of West Bengal used eminent domain to expropriate about 4 km2 of farmland to allow a private company to build a car factory. Violent protest over the low price paid for the acquisition obliged the government of West Bengal to abandon the project, which was eventually relocated to another state.

26 Portland (Oregon) has been one of the first cities in the US to impose an Urban Growth Boundary (UGB) , it consists in a boundary, reviewed every 4 years, which limits the extension of the city to the area within the boundary. A large literature exists on the effect of the UGB on land and housing prices. The UGB concept is applied for all the larger cities in the state of Oregon.

Figure 12: Beaune built-up area and premiers crus vineyards

to establish x2 accurately, this distance would not be optimal for long; agricultural productivity, urban incomes, and transport costs are likely to change over time, requiring a displacement of x2 .

Prices could be distorted in other ways. Agricultural prices could be inflated by subsidized irrigation, for instance, resulting in a misallocation of land, this time at the expense of urban land. Urban land prices themselves could also be distorted by large infrastructure subsidies, transport subsidies, or gasoline subsidies. Governments should correct the misallocation of land between urban and agricultural use through the suppression -- or at least a decrease -- of price distortions, not through design solutions such as zoning regulations.

To remedy perceived excessive urban land consumption, which may or may not exist, planners usually advocate imposing green

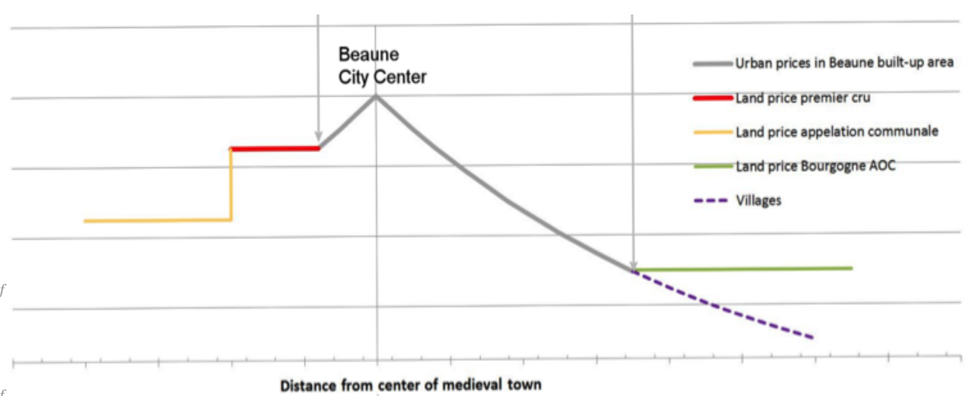


Figure 13: Beaune profile of urban and agricultural land price along ab axis

belts or urban growth boundaries that use design to limit the city expansion. Economic models allow us to understand which conditions might lead cities to consume an excessive amount of land. When overconsumption occurs, it instructs us on what to do to correct it using market mechanisms rather than arbitrarily designed solutions.

Market solutions constantly adjust to changes. Design solutions (for instance, an urban growth boundary a la Portland, Oregon) create rigidities and further distortions.

WHAT HAPPENS TO THE URBAN BUILT-UP BOUNDARY WHEN AGRICULTURAL LAND PRICE IS NOT UNIFORM?

The most simplified form of the standard urban model assumes that the agricultural land price is uniform around a city. Cities where this assumption approximates reality are expected to develop symmetrically around the traditional city center with a built-up area approximating a circle centered on the traditional CBD. This is roughly the case for Beijing, London, and Paris, for instance.

However, the standard urban model implies that where a large difference in agricultural price exists between different directions a city would logically develop in a dissymmetrical way. The city would expand much further toward the cheap agricultural land than toward the expensive land. Let us test the way the standard model adapts in a real city where the price of agricultural land is not uniform in every direction. The city of Beaune, located in the middle of the Burgundy wine country in France, illustrates what the standard model would predict when agricultural land price is much higher in one direction than in another.

Every year, an international wine auction involving some of the most prestigious and expensive wines in the world takes place in Beaune's medieval city center. Beaune plays the role of Wall Street for Burgundy wine. The vineyards providing the most expensive "grand crus" (Aloxe-Corton and Puligny-Montrachet) and "premier crus" Burgundy wines are exclusively located to the West of the city, along gentle slopes exposed to the South-East morning sun, as shown on the map of Figure 12.

The land price of vineyards in this area was estimated at around US $500 per square meter in 2013. This is of course an exceptionally high price for agricultural land. By comparison, the average price of agricultural land in Kansas in 2013 was about US $0.50 per square meter. To the west of Beaune the price of vineyards, because of different soil and sun exposition drops below US $200/m2.

We have to adapt the standard model to reflect the dissymmetrical agricultural land prices around Beaune. Instead of averaging the price of urban land by distance from the city center, as it was done in the previous graphs, let us use the standard model to represent the price of land along an axis AB passing through the city center in a Southeast direction (Figure 12). I represent the profile of the price of urban land prices and the various vineyards' land prices along the axis AB on the graph of Figure 13.

We can see from both the map and the graph that the city expansion is dissymmetrical around the city center as predicted by the model. Toward the northwest, the short distance from the medieval city would make land attractive for development, but urban developers cannot outbid the high "premier cru" vineyard price. The city's built-up boundary toward the northwest is therefore set at a short distance from the city center. By contrast, toward the southeast, the much cheaper price of vineyards where "Bourgogne AOC" wines are produced, which allows the city to expand more freely in this direction. The exceptionally high price of agricultural land surrounding Beaune constrains the expansion of the city and is likely to make urban land exceptionally expensive. Apartments for sale in Beaune near the historical center were advertised at US $4,000 per square meter in 2014.

The Beaune example shows that urban and agricultural prices shape cities. The dissymmetry of Beaune's built-up area has nothing to do with design but reflects market price differences. The very valuable land on which "premier cru" wines are produced does not need to be protected by a green belt or zoning, it is protected by the high price of Burgundy wine on the world market. This example also shows that, when needed, the assumptions of the standard urban model can be selectively relaxed and adapted to circumstances that differ significantly from the initial assumptions.

The land development cost and the limit of urbanization

In the previous paragraphs I have made the assumption that rural land could be converted, without cost, into urban land. In the real world this is usually not the case.

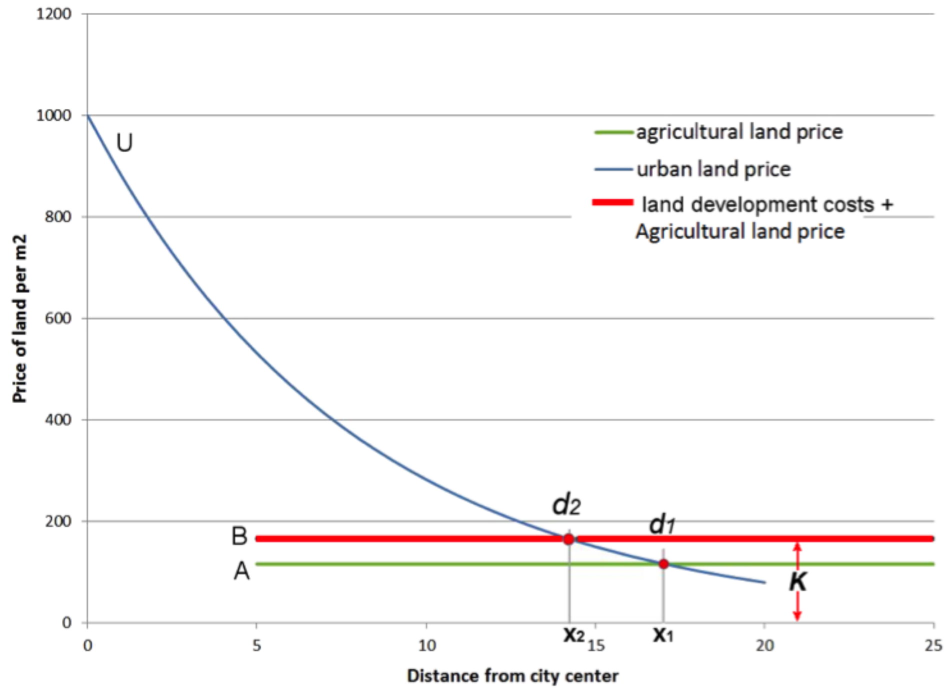


Figure 14: limit of urbanization taking into account the cost of land development

In many cities, land subdivision regulations[27] are setting minimum standards that developers have to meet to transform agricultural land into urban developable lots. Complying with these regulations imposes four types of costs: first, civil work costs for roads, sidewalks, and infrastructure; second, land cost, as some of the land bought from farmers has to be set aside for roads, social facilities and open space; third, overhead costs that include design, supervision and "file pushing" to obtain the various permits from different departments; and fourth, financial cost represented by interest during construction (interest has to be paid on the amount disbursed between the time land is acquired and the time when all the plots are ready to be sold to builders).

The total area of land sold by developers to urban land users is therefore less than the area that developers buy from farmers. The roads and open spaces built by developers are usually transferred free of charge to the local authority. The total cost per square meter of salable developed land that will have to clear the market, i.e. that will be on or below the curve U in Figure 14, is given by the formula:

$$k=(a+c+h+f)/(1-r)$$

Where:

k = land development cost per m2 of salable urban land

a = price of agricultural land per m2

c = cost of civil works per m2

h = developer overhead

f = financial cost

r = percent of developed land to be devoted to roads and open space

27 Land subdivision regulations concern mostly new green field developments. They define 1) the geometry of development -- minimum plot size, minimum street width, minimum areas to be left as public open space, parking requirements, etc. and 2) the construction standards for roads, storm water drains, water and sewer, etc. by contrast, land use and zoning regulations usually concern the restrictions on the type of use (commercial, residential, etc.) and intensity of use (maximum floor area ratio, maximum height, setbacks, etc.) of a specific lot

k represents the development cost of developing land. The profit of the developer will be the difference between k and the sale price of developed land when it will finally be sold to builders. Because it takes a long time (several years for large projects) between the time agricultural land is acquired and developed plots are ready to be sold to builders, the price of developed land at the time of the sale is often quite uncertain[28]. This sale price could be higher or lower than k. If it is lower than k the land developer will have to either take a loss on the project or wait for the price of developed land to increase in the area until it is higher than k. However, during this period the developer will have to pay interest on k, further increasing the cost of developed land.

Comparing the price of agricultural land to the sale price of developed land and assuming that the difference represents the developer profit is therefore completely misleading.

For instance, let us assume that a developer buys land from farmers at $100 per m2, that the cost of civil works, overhead,

28 The market price of an empty lot reflects what consumers are ready to pay for the flow of anticipated rent that the lot will generate over time. This price is usually higher than the original development cost+ agricultural land cost, but not necessarily so. In South Africa, for instance, in large housing projects developed by the government for low-income households, some lots are selling on the free market for only one third of the cost of developing them. I have found the same negative difference between market prices and costs in government-built housing projects in India and in Thailand.

and financial costs amount to $50 per m2, and that regulations require that roads and open space occupy 40% of the land developed. Under these conditions, the price of developed land that will clear the market in this location will have to be at least $250 per square meter[29]. The more “generous” the land development standards imposed by the local authority the higher the price that the final land user will have to pay for developed land.

The land development costs itemized in equation 3 occur only once, at the time when land use changes from rural to urban. The large difference between the sale price of agricultural land at the fringe of cities and the sale price of developed land often gives the impression that either landowners or developers are making an extraordinarily high profit in the process. In reality, most of what appears to be a large capital gain often reflects high values for the parameters c, h, f, and r, reflecting a complex and difficult regulatory process rather than some speculative binge by one player or the other.

The ratio between k and a, relating the price of undeveloped agricultural land to the price of developed land, is an important urban indicator that has been measured in 53 cities across the world by Shlomo Angel during his work on the Housing Indicators Program, conducted in 1994 for the World Bank. Angel calls this indicator the “Land Development Multiplier.” In his book “Housing Policy Matters”[30], Angel analyzes the implications of this indicator for housing affordability. He found that in 1990 the median value of the Land Development Multiplier was equal to 4.0 in developing countries and 2.4 in industrialized countries. This implies that the expansion of cities in developing countries is even more constrained than in industrialized countries, resulting in higher prices for land and housing. A combination of unrealistically high regulatory development standards and high transaction costs due to poor property registration and bureaucratic red tape are the cause of these higher costs.

Let us now revisit the distance between the limit of urbanization and the city center after taking into account the land development costs set by local regulations (Figure 14). Line

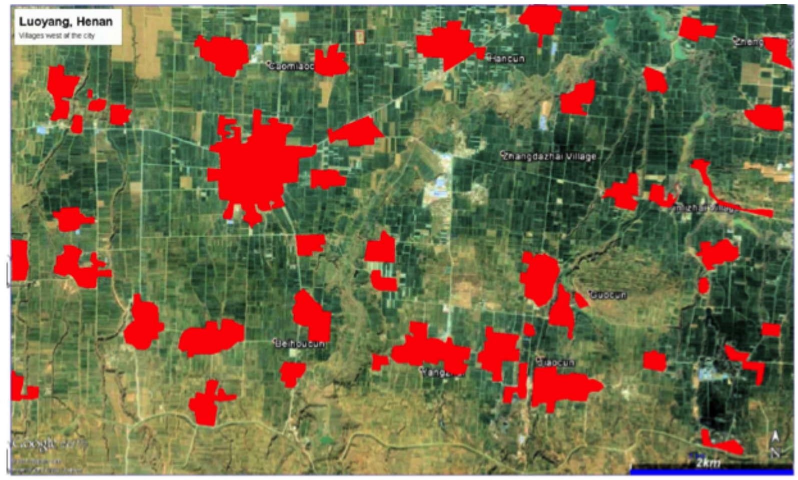


Figure 15: existing villages east of the immediate expansion area of Luoyang, Hena, China

A, which corresponds to the market price of agricultural land (similar to line A on the graph shown on Figure 10), intercepts the urban land price U at the point d1 corresponding to a distance x1. Line B corresponds to the land development cost k (which includes agricultural land price in addition to the other costs of developing land). The intersection d2 of line B with curve U defines the new limit of urbanization for formal land development. We see that when the cost of land development is taken into account the limit of urbanization decreases from x1 to x2, reducing the total area of land developed. The higher the cost k of formal infrastructure development, the shorter the distance x2 compared to x1 and the smaller the total area of developed land -- and consequently the higher the average built-up density, everything else being equal. The value of K, largely defined by planners’ design, has a double impact on developed land cost: it increases the cost of developed land at the edge of cities and it decreases the supply of developable land (by increasing the distance between x1 to x2,), thus increasing the price of land everywhere else in the city.

Regulations impose an urban development limit at x1. However, an informal building sector that ignores regulations exists in many countries. This informal sector includes individuals as well as developers building houses and commercial buildings that do not meet the minimum standards imposed by regulations and therefore for whom the x1 limit is irrelevant. The area between x1 to x2 is likely to become an urban fringe area where the urban labor market will expand by including farmers progressively switching to urban jobs and where informal settlements will

29 Using equation 3 : (100+50)/0.6=250

30 Angel, Shlomo, 2000, “Housing Policy Matters: a Global Analysis”, Oxford University Press develop in countries with weak law enforcement. I will describe in the following paragraphs the conditions under which this extension of the urban fringe will occur.

The labor market may expand beyond x: villages at the fringe of cities

No new formal urban development will normally occur beyond the distance x2 shown on Figure 14. However, farmers already living beyond x2 might find that the difference between urban wages and rural wages are worth the expenses of traveling toward a city job. They already live in a farm beyond x2, they do not have to buy any land to be able to participate in the city's labor market and they do not have to pay land development cost k. If the cost of commuting to the city is lower than the difference between their potential urban salary and their current rural salary, they are likely to decide to join the urban labor force, even though they live beyond the urban built-up boundary. The availability of cheap motorcycles that can move easily on rural roads greatly decreases the cost of individual transport commuting without having to be connected to a major road or transit network. The use of individual transport, when affordable, greatly increases the size of labor markets beyond the visible limits of urbanization. We will see the consequence of the extension of the urban labor markets in rural areas when discussing Hanoi's master plan.

Many cities of Asia are located in the middle of dense rural areas. The population living in rural areas adjacent to big cities often contributes to increase the size of the labor market without requiring migration. This increase might be important in parts of Asia where the rural densities are high, like in Bangladesh, South East Asia, and eastern China. For instance, the map in Figure 15 shows the large numbers of villages located between 20 and 30 kilometers to the east of Luoyang (China). There is no trace of formal urbanization in the area, but a motorcycle would allow farmers to commute to Luoyang in less than 40 minutes. The population of these villages may participate in the urban labor force far before any agricultural land is converted into urban land. These villages are likely to be incorporated into the built-up area of the city when the price of urban land in their area becomes higher than the price of agricultural land.

What type of development might happen between x1 and x2? The emergence of the informal sector and parallel markets

What is likely to happen between x1 and x2? Between these two points[31], at the fringe of cities, farmers are likely to be willing to sell their land to developers at a price higher than the agricultural price. However, formal developers cannot bypass a building permit if they want to apply for construction finance. They will therefore not buy land between x1 and x2, as the cost of development that would meet regulatory standards will not clear the market (between x1 and x2, K is above curve U).

Some consumers, however, may be quite satisfied by land development standards that are lower than the ones prescribed by regulations if they result in cheaper housing. When there is such demand, informal developers, not relying on the formal financial system, will be willing to buy land from farmers and develop it at standards that cost less than K. Between x1 and x2, farmers will only receive an offer for their land at a price above the agricultural price from informal developers. Some farmers might prefer to continue farming and wait for urban land prices to increase further to allow them to sell later to formal developers[32]. However, some farmers may decide to sell to informal developers or even informally develop their own land themselves. In cities where urban regulations make land unaffordable to a part of the population, we can expect to see scattered urbanization made of informal settlements between x1 and x2.

Informal developments might be built by developers in a planned fashion or might be created spontaneously by squatters on government land. Developer-driven informal development is, in my opinion, much more common than squatter settlements although there is no real hard data on the subject worldwide. In this paper I will use the term "informal development" to designate a settlement developed by developers at standards not meeting the regulatory requirements but meeting the demand of a segment of the population, and in general below the cost K as defined in equation 3.

31 We are working here on a simplified version of reality. In real cities the distance from the center to the points x1 and x2 might varies depending on the geographic location.

32 As the population expands, incomes increase, and the price of transport relative to income decreases, both x1 and x2 will eventually shift to the right.

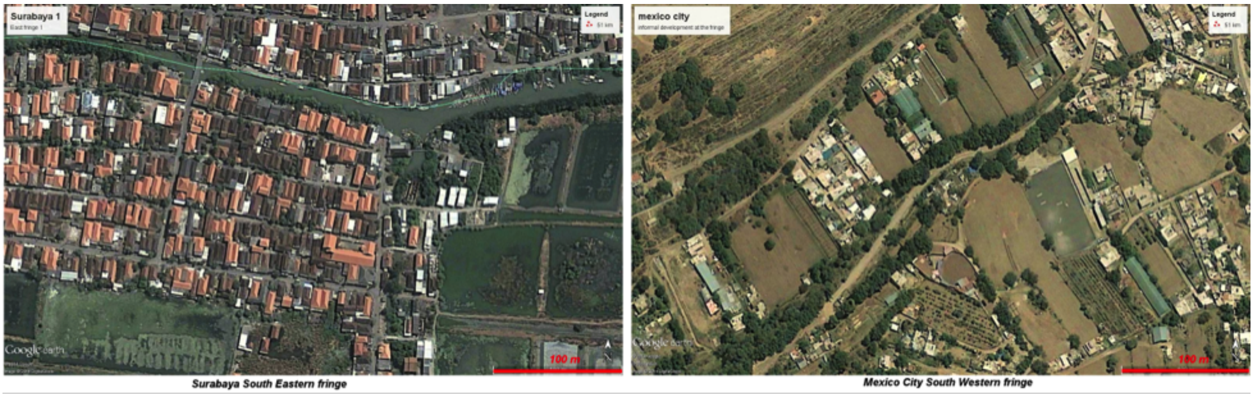


Figure 16: informal subdivision at the fringe of urbanization in Surabaya and Mexico City (same scale)

Informal developments are likely to develop at the fringe of urbanization in cities where the costs of land development are higher than what a part of the population can afford (or is willing to pay). When a large part of the urban population cannot afford the cost of the minimum standards imposed by regulation, the enforcement of the planning rules becomes impossible. In many cities of developing and emerging economies, informal settlements typically represent between 20 to 60 percent of the total housing stock. In Mumbai, for instance, the most prosperous city in India, informal settlements represented more than 60 percent of the housing stock in 2010. The growth of informality is not necessarily driven by poverty but by the arbitrariness and high cost of land use regulations.

In advance economies where new land development is strictly controlled, an informal sector is likely to appear within the built-up area in the form of illegal subdivisions and extensions of existing houses and apartments. A recent paper[33] evaluates at about 114,000 units the number of illegal new dwellings built in New York City between 1990 and 2000. These new units were created by subdividing and expanding legally acquired houses built entirely within existing formal developments. Therefore, the informal sector created by unaffordable urban regulations exists in both developed and developing countries. In developing countries, the informal sector takes mostly the form of illegal land development; in developed countries, illegal subdivisions and extension are more common. The growth of informal sectors in developed and developing countries have the same cause: poorly conceived land use regulations that do not take into account the income of the poorer households.

33 Robert Neuwirth, "New York's Housing Underground: A Refuge and a Resource" Pratt Center for Economic Development and Chhaya CDC (2008).

In countries where land development control is weak, the urban land price curve, defined by the standard urban model, will then correspond to two types of development: new formal development that will be located in areas between the city center and x2, and new informal development that is likely to grow between x2 and x1. Eventually, as household income increases and transport costs decrease, urban land prices will increase pushing the formal development boundary further to the left of x2. Formal and informal development will then be found side by side in the same area, while new informal settlements will develop beyond the new x2 point.

Informal development is a market response to the design rigidity imposed by regulations. Informal land development introduces a form of land supply elasticity in cities where regulations significantly decrease the land supply (x2 is smaller than x1). In the absence of new informal developments, the increase in the supply of housing units for lower income households can happen only through the densification of existing low-income neighborhoods, which reduces the consumption of low-income households. Therefore, the enforcement of urban planning rules frequently contributes to lowering the housing consumption of the poor.

The two aerial images in Figure 16 show informal developments at the fringe of cities in Surabaya (Indonesia) and in Mexico City's Federal District. In Surabaya, villagers have jointly developed agricultural land below the minimum standards for street width and plot sizes established by their government. However, the Indonesian government rightly tolerates this form of development, provided they form an organized community called a Kampong, in many ways similar to a condominium. The local government will later negotiate with the Kampong leadership to connect the Kampong with the municipal networks of infrastructure.

The informal settlements in Mexico City, shown on the right side of Figure 16, are very different. The land development standards -- street width, plot size, setbacks, etc. -- are lower than the ones prescribed by regulations, but the settlement shown is located in an area that is not allowed to urbanize as per the master plan. The settlement is located on a 30% slope in the southwestern part of the Federal district in an area where any development is forbidden for environmental reasons. We can see that the area around Mexico City's informal settlements is still farmed. Regardless of whether or not the area is designated for development by the master plan, the price gradient defined by the standard urban model still defines land prices. Land would probably sell at a discount in an area where regulations forbid any development. But it is the distance to the Mexico City labor market that will ultimately decide the urban land price. If this urban land price is higher than the price of agricultural land the area will likely urbanize. In an area with a 30% slope, agricultural land values might not be very high; therefore the chance that farmers will sell their land to developers is rather high.

I am not giving these examples as advocacy for disregarding all urban regulations. The environmental regulations that aim to prevent development on the slopes of the volcanoes surrounding Mexico City are certainly sound. However, the price of urban land dictated by distance to the city labor market is still there. The designation of non-constructible areas on the master plan does not make the price disappear. Mexico municipalities could enforce these regulations only if they acknowledge the strong economic incentive that poor people have in breaking them. Regulations have a cost. In this case, the cost of the land use regulation is the destruction of the value of the land, owned by the undoubtedly poor farmers toiling on the slopes of the volcanoes. The solution might be to compensate farmers for continuing to farm in the area, providing enough incentive that the informal development alternative will not be attractive to them. Another idea would be to allow for the development of more land that is affordable to low income households in other areas of Mexico City that are not under such an environmental constraint. Whatever the solution, we see the link between land development standards and informality and how the standard urban model can help urban planners anticipate what is likely to happen at the fringe of cities.

3. A CONCRETE APPLICATION OF THE STANDARD URBAN MODEL: AN EVALUATION OF THE HANOI MASTER PLAN

About once every ten years, many cities prepare a new master plan to guide future development. The master plan preparation usually follows the availability of new decadal census results. Typically, a master plan consists of three components. First, a review of past development trends and an identification of current issues; second, a declaration of development objectives and priorities; and third, a proposal for future development -- including a land use map of areas to be developed, a proposal for new zoning regulations, and a list of public investments in civil work and social infrastructure consistent with the implementation of the plan's objectives. In democratically elected municipalities, public hearing and public participation is expected during the various phases of preparation and before final approval by the municipal government.

The need to review periodically and to adjust a city's development objectives and ongoing infrastructure investments is certainly justified. However, whether this review should be done during a massive data gathering exercise every ten years is rather dubious. The traditional master plan exercise seems to be a fossil left over from the time when the planning practices of command economies fascinated the world. It would make more sense for cities to monitor data and indicators in real time and to adjust policy and investments according to what works and what does not, rather than waiting ten years to assess results and eventually changing direction. Some cities like Singapore and Hong Kong have adopted a real time monitoring-adjustment approach for managing their development. Their management system has become more similar to corporations that have to adapt rapidly to external shocks.

The master plan concept is based on the false assumption that city development is similar to large civil work projects, requiring the preparation of a detailed blueprint that will be followed by a construction period of 10 years. While I consider the preparation

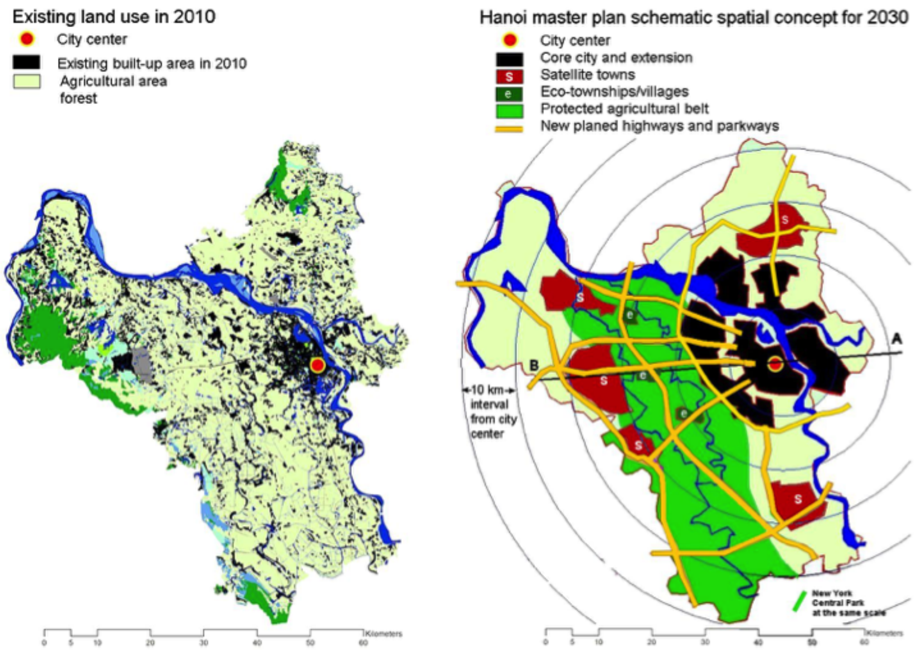


Figure 17: existing land use in 2010 and Hanoi's master plan

of master plans a waste of money and energy, the reality is that most large cities in developing countries hire large engineering consulting firms to prepare these master plans. It is therefore important to look at their impact on the development of cities. Often, many large international lending institutions, such as the World Bank and bilateral development agencies, finance part of the urban infrastructure in developing countries. For these institutions, master plans, "structural plans", or "city strategies" are a convenient way to provide them with a list of potential investments from which they may select their medium term lending program. They therefore tend to support, at times financially, the preparation of such documents, because it simplifies their appraisal process.

Master plans provide a spatial blueprint for the development of cities based on an engineering design approach to city development. Consequently, they usually completely ignore the market forces linking land prices and densities described in the preceding sections of this paper. They use a top-down "design" approach and project the spatial distribution of jobs and people across a metropolitan area based on the preferences of the designer, often justified as a "scientific approach." The master plan for Hanoi reviewed below is unfortunately quite representative of most of the master plans that I have reviewed during the last forty years. We will see that the spatial development blueprint it contains violates most of the theoretical and empirical principles related to the standard urban model.

HANOI: A MASTER PLAN BASED ON "SCIENTIFIC PRINCIPLES"

In 2010, a reputed international consulting firm prepared a master plan for Hanoi, called the "Hanoi Capital Construction Master Plan to 2030 and vision to 2050", projecting population, land use and infrastructure needs for 2030. The plan received the urban design merit award in 2011 from the American Institute of Architects of New York.

Typically, the authors of master plans say that their design for the spatial distribution of population is based on "scientific design principles"[34]. The words "markets" or "land prices" don't appear even once in the entire report, in spite of the declared strategy of the Government of Vietnam to increase the use of market mechanisms to allocate resources. Vietnam acceded to the World Trade Organization in 2007, a decisive step in progressively moving from a command economy to a market economy. There is a buoyant real estate market in Vietnam, with many players ranging from small entrepreneurs to large international developers. In her 2008 book, Annette Kim already described the functioning and peculiarities of the early stage of real estate markets[35]. Since then, the Vietnamese real estate market has

34 This review is based on the report "Hanoi Capital Construction Master Plan to 2030 and vision to 2050 (3rd report – comprehensive text report -11/2009)" The references to "scientific principles" are on pages 41, 54, 55, etc.

35 Learning to be Capitalists: Entrepreneurs in Vietnam's Transition Economy – Oct 2, 2008 by Annette Kim gained in sophistication and its impressive realizations are everywhere to be seen, ranging from low income town houses built by farmers to large urban development that mixes high end commerce, offices and residential towers. No one, walking through the streets of Hanoi, could miss the dynamism and creativity of the various entrepreneurs who are busy building this fast-developing city. In contrast with this on-the-ground reality, the absence of those entrepreneurs in Hanoi's master plan projections is astonishing.

THE MASTER PLAN'S OBJECTIVES

I quote the master plan objectives from the plan's introduction:

> "Among the most important features of the plan is the accepted recommendation that 70% of Hanoi—including its remaining natural areas and most productive agricultural land—be permanently protected from further development as part of a broad sustainability strategy."[36]

Protecting agriculture is explicitly declared to be the main objective that will guide the physical expansion of Hanoi! This is an odd primary objective for the development of a city of 3.5 million in 2012, which grew at 3.5% a year between 2000 and 2010. According to the master plan, the projected population for the metropolitan region will increase to 9 million in 2030. Planning the expansion of the city and a transport system that would allow the labor market to function is likely to become a major challenge. Transportation planning is worthy of significant attention in a master plan, but instead these authors instead focus on preserving agricultural land. Unfortunately, denying the reality that tripling of population will require at least a tripling of developed land will in the long run lead to poor infrastructure. This will be detrimental to the goal of sustainability that the authors purport to pursue.

THE MASTER PLAN SPATIAL CONCEPT: PRESERVING AGRICULTURE

The schematic projected land use plan is shown on the right side of Figure 17. The existing land use map of the metropolitan area in the year 2010 is shown on the left side of the figure. The spatial concept consists of an agricultural belt about 16 kilometers wide splitting the population of Hanoi into two parts: the core city including the current Hanoi's CBD, and high-density satellite towns. Within the agricultural belt, three "Eco-Township/villages" of 60,000 people each will be created, but only agro-industries would be allowed in these "villages". A number of new expressways, parkways and rapid rail transits crossing the agricultural belt would link the satellite towns to the main core city (Figure 17). The land use in 2010 shows that the agricultural belt includes many villages that occupy about 24 % of the area. According to the 2009 census, a population of two million already lives in the villages within the agricultural belt. The authors of the master plan assume that the population already in the agricultural belt will remain rural and will keep cultivating the area.

The concern for the conservation of fertile agricultural land that surrounds the southwestern part of Hanoi is the justification for fragmenting the city's extension on both sides of the agricultural belt. The authors of the master plan provide three reasons to prevent Hanoi's expansion into the immediately adjacent rice paddies. First, the energy saved on transport in bringing rice to Hanoi will be significant compared to the energy required to transport rice from other parts of Vietnam; second, the rice fields would provide a greatly needed green area next to the high-density core city; and third, the existing paddy fields surrounding Hanoi are prone to flooding and would have been expensive to develop.

The master plan does not provide numbers to justify these assertions, which are central to the spatial development strategy. We will see below that the costs that the inhabitants of Hanoi will incur by preventing the urbanization of the agricultural belt will be extremely high and will far outweigh any benefits implied by these arguments. My main objection to the creation of an agricultural belt that would split the city into two parts is that it will disrupt residents' ability to interact with each other and participate efficiently in labor and real estate markets. By ignoring what we know about labor and real estate markets, it will prove to be extremely costly for Hanoi's households and firms.

Let us test the consistency of the master plan spatial concept shown in Figure 17 with what we know about the ways labor and

36 The original master plan land use map can be seen on line at http://www.architectmagazine.com/Images/tmp5699.tmp_tcm20-676650.jpg land markets work. If the spatial extension of the population prescribed by the master plan contradicts the way labor and land markets work, it is unlikely to be implemented because of the high cost that will be incurred by households and firms. Therefore it is likely that the city will grow following a different spatial pattern from the one projected by the plan. Unfortunately, it is also likely that the government will build the infrastructure as planned. This will result in further waste, as the infrastructure will not be built where the new population has settled. This is a common outcome of master plans. I have seen it happen in other cities as diverse as Karachi and Cairo.

THE MASTER PLAN SPATIAL CONCEPT IS INCONSISTENT WITH THE FUNCTIONING OF LABOR MARKETS

The master plan projects that 9 million people will live within the Hanoi Metropolitan area in 2030. Among them, 3 millions will remain "rural", not because they will live in areas that are too remote to participate in the urban labor market, but because they happen to live within the perimeter of what the planners have zoned the "agricultural belt". The agricultural belt, however, is much closer (from 8 to 24 km) to the center of Hanoi than the satellite towns. The current land use map on the left of Figure 17 shows that numerous villages are already located within the projected agricultural belt. According to the 2009 population census, the rural population within the belt is about 2 million people. Many of these villages are already within about 40 minutes by motorcycle from the center of Hanoi. With the new highways planned, the commuting time to Hanoi will become even shorter in the future.

The workers who are currently cultivating rice in Hanoi's agricultural belt are likely to have wages similar to other rice farmers in other parts of Vietnam. If they receive higher wages, then the rice produced in the agricultural belt will have to be sold at a higher price than the rice produced elsewhere, soil productivity being equal. The lower transport cost involved in bringing rice to Hanoi's consumers is unlikely to compensate for the cost of the higher salary of agricultural workers if their wages have to be aligned with those of Hanoi's urban workers. As a result, workers who choose to stay employed in agriculture are likely to have a much lower income than farmers who decide to seek urban employment. The short distance from the agricultural belt to Hanoi's city center will provide a significant employment advantage to farmers seeking urban jobs over the workers in satellite towns located much farther away. The master plan's assignment of workers to rural or urban job is based purely on whether they will live within the arbitrary perimeter of the "agricultural belt", not on distance from urban jobs. In addition, the projected network of highways and rapid rail crisscrossing the agricultural belt will greatly decrease the time required to travel to the center of Hanoi, increasing the opportunity for workers to shift from low rural wages to higher urban wages.

The arbitrary assignment of workers to rural or urban jobs is solely based on planners' choice and is therefore unlikely to be implemented: no zoning regulations can force people to work in one sector of the economy rather than another! It is very likely that in 2030 owners of rice paddy fields in the agricultural belt will face difficulties in finding enough labor to work in their fields, because of the competition with better paying urban jobs. Preventing urban development in the agricultural belt is therefore unlikely to meet its main objective, which was to preserve rice production in this area. Plans that contradict the functioning of labor markets are unlikely to be successful.

THE MASTER PLAN SPATIAL CONCEPT IS INCONSISTENT WITH THE FUNCTIONING OF LAND MARKETS

The villages currently within the agricultural belt occupy about 23% of the belt area (Figure 17). As soon as the planned road infrastructure would be built, the transport time and cost toward Hanoi's main employment areas will likely decrease. Consequently, the price of houses in these villages will increase and will likely follow an urban price gradient centered on Hanoi's city center, as predicted by the standard urban model. The likely high rent generated by floor space located in these villages will be a strong incentive for farmer to increase the number of floors of existing houses or to build new ones in their backyards. The area is likely therefore to densify, sheltering the families of urban farmers and additional urban workers. The density in these villages will increase in the same way that the density in the villages in Hanoi's closer periphery has increased in the past.

The cultivated land around the villages of the agricultural belt will of course be under the same developmental pressure as the land occupied by villages. Originally, the price of land in the agricultural belt will reflect the income generated from cultivating rice. But as urban households' incomes increase and transport cost to the center of Hanoi decreases, the demand for urban land from households and firms will increase. Consequently, the price of land in the agricultural belt will increase and become much higher than the price of land under agricultural use. The profile of land prices and densities will follow the profile predicted by the standard urban model and will be similar to the graph of Figure 10, with the peak land price and density at Hanoi's CBD. We may safely assume that most of the agricultural land within the planned agricultural belt will soon have an urban land value much higher than its agricultural value. Already, observations of Google Earth imagery taken in 2014 show that a number of new formal and informal housing developments are taking place in the agricultural belt, consistent with the predictions of the standard urban model.

THE SPATIAL DISTRIBUTION OF POPULATION AS DESIGNED BY THE MASTER PLAN IS UNLIKELY TO EVER BE IMPLEMENTED

It is unlikely that regulations, even if the government were ready to enforce them, would be enough to prevent urban development in the agricultural belt. In principle, all land in Vietnam belongs to the state. However, farmers have a collective land use right to the land they occupy and, since the reforms of 2005, farmers have been allowed to sell land to developers, though the local government often intervenes as an intermediary, getting substantial revenue in the process.

Under the spatial concept of the plan, farmers outside the agricultural belt would therefore be allowed to sell their land to developers, raising substantial revenues for themselves and the local government, while farmers inside the agricultural belt limits will have no other option but to keep growing rice on it. Obviously, there would be a lot of political resistance, in particular because the limit establishing the agricultural belt is arbitrary. Farmers, local government, and developers will lose a lot of potential revenue because of the creation of the agricultural belt; they will form a powerful coalition to prevent its implementation. Households seeking low rents or cheap housing in areas with good job accessibility would prefer to settle in the agricultural belt than to be forced to live in satellite towns at a much longer distances from jobs.

The apparent drop in land value caused by the interdiction to build the agricultural belt may also become a large source of inequity and corruption. Local government could expropriate farmers from their land, paying agricultural land prices for it – as officially this would be the only use permitted. Later, an unscrupulous intermediary could resell the land to a developer at a much higher price after obtaining an amendment to the master plan by creating enclaves of urban development in the agricultural belt.

WHAT WOULD THE CONSEQUENCES OF CONSTRUCTING THE INFRASTRUCTURE DESIGNED IN THE MASTER PLAN BE?

Because the planners who designed the master plan failed to understand the way labor and real estate markets work, the spatial distribution of densities in 2030 are likely to be very different from the designed densities shown in the plan. Higher population densities will be concentrated in the eastern part of the agricultural belt, decreasing toward the West. If the government implements the infrastructure investments programmed in the master plan, there will be a mismatch between the infrastructure built and the actual spatial distribution of the population. The new dense developments that will emerge in the green belt will generate many trips with no matching road and transport network. The large, newly urbanized areas within the agricultural belt will be deprived of a comprehensive sewer and drainage network that could protect the environment and prevent periodic flooding. Indeed, the protection of the rice paddies of the agricultural belt will require the conservation of the current irrigation network. An urban storm drainage system preventing seasonal flooding is incompatible with irrigation. Eventually, at a much later period, when the agricultural belt is fully urbanized, the government will have to build a comprehensive sewerage and drainage system as is being done in Bangkok and Jakarta, but at a far greater cost than if it had been designed before urbanization had taken place. Building a regional storm drainage and sewer system in the monsoon countries where Hanoi is located requires complex hydrological studies of the area, which have not been conducted because the agricultural belt is meant to remain rice paddies.

The lack of well-designed recreation areas will be another casualty of the master plan. The plan considers the rice paddies a "green reserve" by themselves and consequently does not identify specific areas in the agricultural belt reserved for recreation. As the rice paddies are progressively replaced by informal urbanization, strategically well-located open spaces may well disappear. Two rivers cross the agricultural belt, feeding a number of ponds and small lakes. In view of the inevitable urbanization of the agricultural belt it should have been indispensable to delimitate a buffer zone around the existing water bodies that would become formal public parks and used in conjunction with the urban storm drainage system.

WOULD THERE BE ANY SOCIAL BENEFITS IF THE GOVERNMENT COULD ENFORCE THE SPATIAL DISTRIBUTION OF POPULATION PRESCRIBED BY THE MASTER PLAN?

Most master plans have the same flaws as Hanoi's master plan and consequently are not implemented. Eventually, through derogations to the plan or the growth of the informal sector, the distribution of densities and land prices follows the pattern corresponding to demand for land from households and firms, as predicted by the standard urban model. This is certainly what will happen in the case of Hanoi's master plan.

However, we could try to evaluate what the impact on the welfare of Hanoi's populations would be in case an authoritarian government, through a draconian enforcement of land use regulations, could succeed in preventing urban development in the agricultural belt. We could assess this welfare through two indicators: the affordability of land and the average commuting distance.

The impact the plan would have on urban land and housing prices is obvious. The agricultural belt covers 870 square kilometers, an area slightly larger than the 850 square kilometers planned for the total built-up area of Hanoi in 2030! Removing such a large area from the land supply would increase land prices in the residual area where the plan authorizes urban development. It would also further increase densities in the already very dense core city, increasing congestion and decreasing the land and floor consumption of the poorer households. The impact of green belts on land and housing prices has been well documented by many urban economists like Jan Brueckner, Edward Mill and Kyung-Hwan Kim.

The implementation of the plan would also significantly increase commuting time and energy used by urban transport compared to what it would have been if development prices and densities had followed the standard urban model. The agricultural belt – from 20 to 30 kilometers wide – separates the core city from the satellite towns. This distance will add to the commuting time for those who live in the satellite towns but work in the core city and for those who live in the core city but work in the satellite towns. Would the implementation of the master plan create any benefits that could compensate for the higher cost of housing and transport? The master plan mentions three major benefits that would be directly derived from its proposed spatial arrangement: first, the agricultural belt will save on the cost of transport for the rice consumed by Hanoi's urban population; second, the agricultural belt will provide a useful green space for recreation; and third, by avoiding development in rice paddies it will decrease the cost of infrastructure development.

The argument that creating an agricultural belt in the middle of Hanoi's metropolitan area will save on agricultural transport cost is na ve at best. The dense highway network designed to link the two parts of the city shows that the planners are well aware that intense commuting will take place between the two parts of the city. The agricultural belt will significantly increase commuting length and cost, as can be seen on the map of Figure 17. If there are any savings in transport cost when shipping rice grown in the agricultural belt, they are likely to be insignificant compared to the increase in commuting cost. It would be much cheaper to transport rice once a year after harvest from any location in Vietnam than to transport millions of people twice a day across Hanoi's metropolitan area.

The second argument – the agricultural belt would constitute a needed recreation area – is not more valid. The rice paddies that occupy the agricultural belt in the master plan would be a poor recreational area considering that they are flooded a large part of the time. The area represented by the agricultural belt is about 10 times the area of Hanoi's core city. It would be large enough to fit more than 300 parks the size of New York's Central Park! If the agricultural areas around Hanoi were urbanized it certainly would be possible to reserve recreational areas along the two rivers and the several lakes consisting of large and pleasant green space that is highly accessible to adjacent neighborhoods. Hanoi already has many examples of well-designed and well-used parks along rivers and lakes in the middle of dense neighborhoods.

The third argument, that paddy fields are prone to flooding and are expensive to develop, is somewhat more valid than the first two. However, in 2010, villages inhabited by a population of about 2 million people already occupied 23% of the area within the agricultural belt. It therefore seems that the area is not impossible to develop. Anyway, it would be even more expensive to develop a network of highways and rapid transit (map of Figure 17) across the same paddy fields as the ones proposed by the master plan without developing the land adjacent to the highways. Many large cities of South East Asia, among them Bangkok and Jakarta, have been developed on former paddy fields. Land development in paddy areas requires careful planning of an elaborate drainage system, but it is commonly done all over South East Asia.

THE DIAGNOSTIC OF HANOI'S MASTER PLAN: ALLOCATING URBAN LAND AND ACTIVITIES IS NOT A PURE DESIGN EXERCISE BUT REQUIRES AN UNDERSTANDING OF HOW LABOR AND LAND MARKETS WORK

The problem with Hanoi's master plan is not caused by an unfortunate design decision but by a faulty concept. It is impossible to design the future expansion of a city without taking into account the impact of the labor and land markets on the future distribution of the population. Land prices, rents and commuting time are not mentioned even once in the master plan's nearly thousands pages of text, maps, and tables. It is a rather typical document that exposes the hubris of planners who think that a city needs only to be designed by a clever engineer, without taking into account market mechanisms that are constantly at play. Contradicting markets always have grave consequences. Labor and land market mechanisms are not abstract concepts; they represent a synthesis of informed individual choices made by households and firms. The aggregation of individuals' choices creates cities; urban planning is just there to assist in coordinating the building of the infrastructure needed to accommodate a large concentration of people.

The standard urban model has shown us that the price of land in large cities is similar to the gravity field of large planets that decreases with distance at a predictable rate. Ignoring land prices when designing cities is like ignoring gravity when designing a space rocket.

4. THE OPERATIONAL APPLICATIONS OF THE STANDARD URBAN MODEL

An understanding of the standard urban model is indispensable when making informed choices to manage cities. Let us summarize the operational implications of the spatial distribution of prices and densities as derived from the model. Concerns for an over-consumption of land by cities are best addressed by identifying possible distortions in the land market caused by an abusive use of eminent domain that underprices agricultural land. Setting arbitrary spatial barriers to urban expansion, such as green belts and urban growth boundaries, results in higher land and housing prices.

Land prices and population densities are closely related and are produced by market forces. We have also seen that there is no optimum density for urban development and that within the same city densities may vary by order of magnitude from the center to the periphery. The population density in a particular neighborhood is determined by trade-offs between households' desire to consume more land and floor space and the commuting cost in time and money. Households with different preferences and incomes make different trade-offs. Some low-income households prefer to reduce drastically their land and floor space consumption in order to reduce commuting costs. Other households with similar income may make different trade-offs. Planners cannot possibly know the reasons that households may have in selecting a specific housing location and land consumption. Therefore, planners should abstain from arbitrarily fixing densities through regulations. Neither should they try to distribute population according to a designed spatial pattern no matter how clever the geometric arrangement appears to be.

Planners should use the standard urban model to better understand how markets work in the city they are managing. They can use the model to anticipate the effect of regulations and infrastructure on land prices and rents. They can plan, finance and build the infrastructure that would increase the supply of land and therefore decrease housing cost. They can design transport systems that decrease commuting time and cost, another way of increasing the supply of land and increasing mobility. They should design transport systems that are consistent with the densities set by the land markets rather than design densities that would make a preselected transport system feasible.

In general, fixing minimum consumption for land and floor space through regulations such as minimum plot size, maximum floor area ratio, and maximum number of dwelling unit per hectare introduces rigidities in the market that have negative impacts on poorer households for whom these regulations are binding. Planners should therefore abstain from using these regulatory constraints on minimum land and housing consumption as they hurt the poor the most and trigger the growth of informal markets.

Only after they have a good understanding of how local real estate markets function can planners anticipate future land market values to plan infrastructure networks that will be consistent with anticipated densities. Constant monitoring of land prices and rent could provide planners with feedback that could help them amend their infrastructure plans if their projection appears to diverge from reality.

Unaffordable housing is a plague affecting many large cities. Monitoring the ratio between median income and median housing price allows us to constantly measure housing affordability. When the price to income ratio becomes higher than 4, planners should take immediate action. This action could be to increase land supply through new infrastructure development or to audit land use regulations and building permit practices that may make developed land and housing prices abnormally high. Urban planners should be held responsible for unaffordable high price/income ratios in the same way that public health officials are held responsible for infectious disease epidemics, or police are held responsible for high crime.

In the case of Hanoi's master plan, planners should have surveyed house rents and the price of land in new housing developments in the agricultural belt. If they had done so, the very high cost imposed upon the two million farmers already living there by preventing further development in the agricultural belt would have become evident. A quick survey of agricultural wages compared to urban wages would have also allowed them to anticipate that most agricultural workers would eventually switch to urban jobs as soon as they had access to them through better transport networks. The lack of understanding of land and labor markets led the planners to design a metropolitan infrastructure that will be at odds with the likely spatial distribution of the population.

The standard urban model is a very crude instrument that provides an understanding of the basic movement of land prices and rent when income, transport costs, and land supply change over time. Planners could design more complex models to anticipate price movements or commuting patterns in cities with specific constraints, in particular topographical constraints like bodies of water or steep mountains. However, no infrastructure or regulatory design decision should be taken without accounting for its impact on the land market.