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Discontinuous Urban Development and Economic Efficiency†

James C. Ohls* and David Pines**

INTRODUCTION

It has frequently been noted that urban land markets are characterized by discontinuous development. Critics of such markets have observed, for instance, that the urban development process seems frequently to skip over land closer to the center of urban areas in favor of land further away. This, they argue, is inefficient both because it fails to make use of the most accessible land and also because certain urban public services such as roads and sewage systems may be relatively expensive in the context of such development.

That there are costs associated with discontinuous development cannot be denied. However, it has also been observed in the literature that such discontinuous development has benefits as well as costs and that land markets which produce such development patterns may therefore not be as inefficient as their critics have suggested. In particular, previous authors have shown that discontinuous development patterns may be desirable if there is imperfect knowledge about the future [Boyce 1963] and/or if there are externalities (nonmarket effects) present in the market [Lessinger 1962]. While these previous articles provide considerable insight in understanding and assessing the urban development process, we believe that there are additional reasons for discontinuous development which may have important policy implications but which have not been recognized in the existing literature.

In subsequent sections of this paper, therefore, we discuss two additional reasons why discontinous development may sometimes be efficient. These additional arguments depend neither on imperfect knowledge nor on the existence of externalities. Rather, one of them is based on a trade-off between living space and accessibility over time, while the other is based on the fact that the development of retail and commercial services near the urban fringe must often await the development of markets large enough to exhaust economies of scale.

DISCONTINUOUS DEVELOPMENT AND THE TRADE-OFF BETWEEN LIVING SPACE AND ACCESSIBILITY THROUGH TIME

In this and the following sections of the paper, we proceed by constructing highly simplified models of urban areas and then showing that, under certain conditions, discontinuous development will be efficient in the context of the models. The examples which we con-

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struct are simplified ones with many highly restrictive assumptions. In general, however, the qualitative results we obtain are independent of the assumptions. The assumptions serve to keep the models relatively simple and thus to highlight basic insights.

Our first model is based upon the concept of a trade-off between living space and accessibility. Consider the following simple dynamic allocation problem: $2x$ housing units are to be located as efficiently as possible in each of two periods within the boundaries of a city which is divided into three zones. Suppose that two densities are possible, high and low, with the higher density being associated with higher construction costs and/or with a lower welfare level. Assume too that the zones differ with regard to accessibility to work places in the center of the city.

More specifically, the problem is the following:

(a) $2x$ housing units are to be allocated in period 1, and an additional $2x$ housing units are to be allocated in period 2.

(b) Two densities are possible:
x units per zone
$y(=2x)$ units per zone
Higher costs and/or lower housing welfare levels are associated with the higher density.

(c) Zone 1 is the nearest to the center of work, and the transportation costs associated with a unit of housing located there are the lowest. Zone 3 is in the most remote location and therefore the transportation costs for units located there are the highest. Zone 2 is located between zones 1 and 3 and hence is intermediate in distance from the city center.

(d) It is necessary to choose the most efficient program from the set of alternatives.

Table 1 shows the 12 alternative programs which provide for the allocation of $y(= 2x)$ housing units in each of the two periods. (We assume demolition of already existing buildings is prohibitively expensive and can be ignored.)

The planning problem which we have outlined involves choosing from among these 12 programs the one which minimizes costs, where costs include transportation costs, construction costs, and welfare losses from having to live in high-density, rather than low-density, housing. Our main interest is in whether it is ever efficient to choose one of the programs (2, 3, 7, 8, 9, 10, 11, or 12) which involve skipping over land relatively close to the city center in order to build on land further out.

It is clear immediately that it will never be efficient to pursue any one of programs 6 through 12. This is clear because each of these programs is strictly dominated in terms of accessibility and density by at least one of programs 1 through 5. For instance, consider program 7. This program implies higher transportation costs in both periods than does program 4 while the densities associated with programs 7 and 4 are the same in each period. Hence program 4 clearly is more efficient than 7.

After eliminating programs 6 through 12, which are clearly dominated, we are left with 5 programs, two of which (2 and 3) involve discontinuous development. In order to compare these programs, we must be more specific in our assumptions regarding costs. Therefore, we shall adopt the following notation:

TABLE 1

ALTERNATIVE DEVELOPMENT PROGRAMS

	Stage 1				Stage 2			
	Zone				Zone			
Program	1	2	3	1 + 2 + 3	1	2	3	1 + 2 + 3
1	x	x		$2x$	x	x	y	$2x + y$
2	x		x	$2x$	x	y	x	$2x + y$
3		x	x	$2x$	y	x	x	$2x + y$
4	y			y	y	x	x	$2x + y$
5	y			y	y	y		$2y$
6	y			y	y		y	$2y$
7		y		y	x	y	x	$2x + y$
8		y		y	y	y		$2y$
9		y		y		y	y	$2y$
10			y	y		y	y	$2y$
11			y	y	y		y	$2y$
12			y	y	x	x	y	$2x + y$

C_1 = per household costs associated with low-density housing unit (current value).

C_2 = per household costs associated with high-density housing unit (current value).[1]

t_j = transportation costs per unit of time of a household located in zone j, (j = 1, 2, 3). It is assumed that transportation costs do not vary with time.

i = the rate of discount per period. If one period is taken to be one year, i is simply the relevant annual interest rate. If a planning period is taken to be several years, i is $(1 + r)^n - 1$ where r is the annual interest rate and n is the number of years per period.

Using the above notation, the costs of the programs can be represented by Table 2.

The cost of each of the programs is simply the sum of the relevant five entries times the corresponding column headings. After writing the costs in this way, it becomes clear that one of the programs involving discontinuous development, program 2, can never be efficient. This can be shown as follows: Since the first three entries in Table 2 are identical for programs 1 and 2, in order for 2 to be preferred to 1 the following relation must hold:

$$\frac{t_2}{i} + \frac{2t_3}{i(1+i)} > \frac{2t_2}{i(1+i)} + \frac{t_3}{i}$$

and, since $t_2 < t_3$ by assumption, this implies $i > i^2$.

[1] We shall assume that $C_2 > C_1$—i.e., that high-density dwellings cost more. Alternatively, the difference between C_2 and C_1 can be interpreted as the welfare loss to households from being in dense housing.

TABLE 2

COSTS OF ALTERNATIVE PROGRAMS

Program	Cost				
	C_1	C_2	t_1	t_2	t_3
1	2	$\frac{2}{1+i}$	$\frac{1}{i}$	$\frac{1}{i}$	$\frac{2}{i(1+i)}$
2	2	$\frac{2}{1+i}$	$\frac{1}{i}$	$\frac{2}{i(1+i)}$	$\frac{1}{i}$
3	2	$\frac{2}{1+i}$	$\frac{2}{i(1+i)}$	$\frac{1}{i}$	$\frac{1}{i}$
4	$\frac{2}{1+i}$	2	$\frac{2}{i}$	$\frac{1}{i(1+i)}$	$\frac{1}{i(1+i)}$
5	0	$2+\frac{2}{1+i}$	$\frac{2}{i}$	$\frac{2}{i(1+i)}$	0

Note: Construction costs, C, are treated as lump-sum costs in the year that they are undertaken and are discounted back to period 1 accordingly. The flows of annual transportation costs are capitalized assuming an infinite time horizon and are discounted back to period 1.

But in order for 2 to be preferred to program 3, the following relation must hold:

$$\frac{t_1}{i} + \frac{2t_2}{i(1+i)} < \frac{2t_1}{i(1+i)} + \frac{t_2}{i}$$

which implies: $i < i^2$.

Hence, program 2 cannot be simultaneously preferable to both 1 and 3. The type of discontinuous development implied by program 2 is ruled out.

Can the other program which involves sprawl be optimal? The answer is yes. Program 3 can be shown[2] to be preferable to program 1 if $i > i^2$. This condition also implies that program 3 is preferable to program 2.

Program 3 is preferable to program 4 if:

$$2C_2 - 2C_1 > \frac{\frac{1}{i} - \frac{1}{i(1+i)}}{1 - \frac{1}{1+i}} (t_2 + t_3 - 2t_1)$$

or

$$2C_2 - 2C_1 > (t_2 + t_3 - 2t_1)/i$$

It is also preferable to program 5 if:

$$2C_2 - 2C_1 > [\frac{1}{i} - \frac{1}{i(1+i)}] (t_2 + t_3 - 2t_1) + \frac{1}{i(1+i)} (t_3 - t_2)$$

or

$$2C_2 - 2C_1 > \frac{1}{1+i} (t_2 + t_3 - 2t_1) + \frac{1}{i(1+i)} (t_3 - t_2)$$

The above relations imply that program 3 is efficient if:

(a) $i > i^2$

[2] The proof is similar to those above.

(b) $2C_2 - 2C_1 > (t_2 + t_3 - 2t_1)/i + (t_3 - t_2)$

$$/[i(1+i)]$$

Since these conditions are not mutually inconsistent, we have shown that it is possible for discontinuous development to be the most efficient pattern of land use over time in this model. Program 3 involves building at lower densities in the outer zones of the city during the first period and then building at higher densities in the inner zone during the second period. The insight behind the above proof that this may sometimes be efficient is the following: In the context of a rapid-growth city, the most efficient ultimate equilibrium for the city may include high densities in the center. However, if people prefer lower densities (or if lower costs are associated with lower densities) it may make sense initially to build lower-density housing relatively further from the city center to accommodate this desire for low density as much as possible, while at the same time reserving the central land for its ultimate high-density development.

It may be of use to discuss the meaning of the conditions derived above at an intuitive level. Condition (a) requires that the discount rate not be extremely high.[3] This is a necessary condition because if the discount rate were very high, future costs would never be important relative to present costs and hence it would never be efficient to incur high transportation costs in the first period by building relatively far from the city center in order to save future construction and transportation costs.

Condition (b) requires that the disadvantages associated with higher density (including possible money cost and loss of welfare) be substantial relative to the transportation costs. If this is not the case, programs 4 and 5, which save transportation costs at the expense of higher housing costs, will be preferable to program 3. Condition (b) also requires that the discount rate not be extremely low. This is a necessary condition because otherwise the saving in density cost, resulting from deferring the dense development to the future, is relatively small and therefore does not justify the higher cost of transportation in the first period.

In closing this section, it may be appropriate to comment on the empirical relevance of the above conditions. Since our basic purpose in this paper is to alert planners and others interested in urban land use to the possibility that discontinuous development may be efficient, we have created a very simplified, stylized model in an effort to highlight the relevant issues as clearly as possible. As a result, it is probably not possible to apply the model directly to available data. At a more general level, however, our own judgment is that the insights of this model do, in fact, have potential relevance to real planning situations. In particular, we believe that they may well apply to new and rapidly growing cities where population may change by orders of magnitude within a few years and where residential densities at the center which are consistent with the ultimate size of the city may be far greater than those which would seem appropriate in the earlier stages of urban growth. Certain cities in Israel, for instance, have experienced this sort of extremely rapid growth during recent decades, and indeed it was these cities which we had in mind as we developed the model.

[3] If the planning period is 1 year, for example, condition (a) requires that the annual interest rate be less than 100 percent. If the planning period is 7 years, the ceiling implied by the condition is 10 percent. If it is 12 years, the ceiling is 6 percent.

TABLE 3

LOCATIONS IN HYPOTHETICAL CITY

	Tract											
	1	2	3	4	5	6	7	8	9	10	11	12
Employment and Retail Center	x	x	x	x	x	x	x	x	x			
	Contain Housing									Vacant		

RESERVING LAND FOR COMMERCIAL DEVELOPMENT

The previous section showed that in a situation where there are alternative possible residential densities it may under some circumstances be most efficient to have discontinuous development. In that discussion the skipped-over land was reserved for residential development in a later period at a different density than that used in the first period.

In this section of the paper we demonstrate another possible reason why discontinuous development patterns may be efficient. Specifically, we show that it may be efficient to bypass land in order to reserve the skipped-over land for commercial use at some future time. As in the preceding section, the example we use is simplified in order to highlight its basic insights.

Assume that an existing city is laid out as shown in Table 3 with a business district and employment center at one end and nine tracts of housing, each containing population x.[4]

Everybody works at the employment center, and the cost of getting there and back is t_w per tract per period. For instance, the households living in tract 3 shown in Table 3 have to go across two tracts (tracts 1 and 2) in order to work and hence must pay $2t_w$ in commuting costs each period. T_w is the present discounted value of a stream of t_w payments over the entire lifetime of a housing unit. Since this lifetime is assumed to be lengthy, t_w can be approximated by $T_w = t_w/i$, where i is the discount rate in the economy. The costs of making shopping trips, t_s and T_s, are defined analogously.

A retail service center requires one tract of land and requires C_s of capital costs to construct. These requirements are independent of the number of people served. Operating costs for the shopping center are negligible. People's demand

[4] We have chosen the highly simplified and rather unusual shape for the city shown in Table 3 for convenience of exposition. Our purpose is to show the possibility—rather than the certainty—of discontinuous development being efficient, and the city of Table 3 will suffice for that purpose. At the cost of greater complexity, the basic insights developed in this section could be generalized to more reasonably shaped cities. However, we do not mean to imply by this that our results about the efficiency of discontinuous development will hold for all shapes of cities in all situations.

for shopping services is assumed to be perfectly price and cost inelastic—the number of shopping trips a household makes is independent of its distance from a commercial center. Commercial services are assumed to be priced at the cost of the merchandise plus a mark up.

Only one density of housing—x people per tract—is possible. Demolition of housing once it is built is assumed to be prohibitively expensive and therefore is not considered. Assume that population will increase by x in each of the next two periods.

The planning problem in this simple model is the following: we must determine whether it is economically efficient to construct a second retail center, and, if it is efficient, we must determine when (which of the next two periods) and where (on which of the three vacant tracts on the city's edge) it should be constructed.

It is clear immediately that it would not be efficient to build the first period's housing further from the employment center than the second period's housing. To do so would increase commuting costs in the first period without any corresponding saving in construction or shopping trip costs. Hence, we can eliminate possible solutions to the planning problem which involve the first period's housing being further from the employment center than the second period's housing. This leaves us with 7 possible solutions to the planning problem, as shown in Table 4, where x denotes the construction of housing and s denotes the construction of a shopping center. For instance, Solution A is the alternative under which no shopping center is built. Solution B is the alternative where, in the first period, housing is built in tract 10 and the shopping center is built in tract 12, and in the second period housing is built in tract 11. Our interest

TABLE 4

ALTERNATIVE DEVELOPMENT PROGRAMS

		Tract 10	Tract 11	Tract 12
A	Period 1	x		
	Period 2		x	
B	Period 1	x		s
	Period 2		x	
C	Period 1	x		
	Period 2		x	s
D	Period 1	x	s	
	Period 2			x
E	Period 1	x		
	Period 2		s	x
F	Period 1	s	x	
	Period 2			x
G	Period 1		x	
	Period 2	s		x

is in determining whether there are conditions in this model under which one of the two solutions involving discontinuous development (solutions B and G) will be efficient.

The answer to this question is that in fact there are such conditions and that, in particular, it can be shown that solution G to the planning problem outlined above will be efficient if the following conditions are met:[5]

[5] The proof of the sufficiency of these conditions for plan G to be efficient is somewhat lengthy and tedious and adds no additional basic insight to the analysis. Hence, in order to conserve space, we have omitted the proof from this published version of the paper. It is available from the authors upon request.

$$30T_s \leqslant \frac{C_s}{1+i} \leqslant 30T_s + t_w \tag{1}$$

$$t_w + \frac{T_w}{1+i} \leqslant \frac{2T_s}{1+i} \tag{2}$$

$$i < 0.1 \tag{3}$$

Clearly these conditions are mutually consistent, and hence temporarily skipping over land may be efficient. The basic intuition behind this result is the following: even if the current market size in a growing area does not justify a commercial center, it may make sense to reserve highly accessible land in that area so that a commercial center can be efficiently located in the future, when greater market size warrants its construction.

In closing this section it may be useful to indicate intuitively what the three conditions derived above require. Plan G involves placing the shopping center as centrally as possible to the suburban market and waiting until the second period to build it. Condition (2) is simply that work trip cost not be too large in relation to shopping costs. This condition is necessary because putting the shopping center on tract 10 rather than, say, tract 12 forces residential development to occur further out from the work center and hence results in greater commuting costs. This will only be efficient if these increased commuting costs are not too great in relation to the shopping trip costs which can be saved with the relatively more central location of the shopping center.

The left-hand side of Condition (1) states that shopping-trip costs not be too large in relation to the capital costs of construction. This condition is necessary because otherwise it would not make sense to wait until period 2 to build the shopping center. If, for instance, C_s were negligible it would be efficient to build the shopping center at the first possible moment—i.e., in period 1. It is only because of the capital costs that it may be efficient to wait until period 2 when the potential market is larger and hence when total travel savings resulting from having a shopping facility at the periphery of the city are greater.

The right-hand side of Condition (1) places a limit on the size of capital costs in relation to shopping trip costs. This is a necessary condition because, intuitively, if capital costs were very high in relation to shopping-trip costs, it might never be efficient to build a shopping area in the periphery of the city at all and hence Plan A, in which no shopping area is built, might be efficient.

Finally, Condition (3) puts an upper limit on the discount rate.[6] This is necessary because, if the discount rate were extremely high and hence if future costs were discounted very heavily, it would never be efficient to bypass land in the first period, thus increasing work-trip costs in that period, in order to gain benefits in the second period. Also, if the interest rate were high, that would diminish the attractiveness of building any shopping center at all since such a project is an investment with present costs and future benefits.

As in the previous case analyzed, the shopping center example which we have developed above is probably too stylized to make it possible to give direct empirical content to the conditions discussed in the previous paragraphs. Again, however, we believe that the general insights

[6] The exact value of this limit (e.g., 0.1 in the previous discussion) depends on the exact specification chosen for the illustrative model we have used. Other specifications would yield different upper limits.

illustrated by the example may have quite common applicability. In rapidly expanding urban areas in both the United States and elsewhere, there are, we believe, frequently contexts in which it may be efficient to skip over land for a period of time in order to reserve it for commercial uses after market sizes increase. Indeed, it is interesting to note that this has, in fact, been done in some planning contexts in the United States. For instance, the planners of the "new town" of Columbia, Maryland, have explicitly reserved vacant land in residential areas for development of shopping clusters in the future after increased residential densities make such shopping enterprises economically feasible.

SPECULATION, SPRAWL, AND EFFICIENCY

In previous sections of this paper we have shown that discontinuous development patterns may in some cases be efficient. We have not, however, considered the question of whether government policy is needed to ensure these efficient patterns of development, and it is to this question that we now turn.

In particular, we shall focus in this section on the role of speculation in land markets as a possible mechanism for ensuring economic efficiency without government intervention. In the past, speculation has often been said to distort economic calculations which otherwise would lead to correct allocation. In some circumstances, however, speculation may be exactly the mechanism that leads to efficient allocation.

The basic idea behind this concept is simple. When a piece of land has the potential for being highly productive at some future date if kept vacant until that time, then it will be in the economic interest of potential owners to buy the land, hold it vacant for a while, and then either develop the land themselves or else sell the land in the future at a relatively high price reflecting its high productivity at that time. As long as several potential owners are aware of this possibility of future profit, they will, in competing for the land, bid its current price up to a value which is high enough to reflect its future profitability. And it is exactly this high speculative price of the land which discourages premature development and thus reserves the land for its more productive future use.

It should not be inferred from the above that private market speculation can *always* be relied upon to ensure efficient development patterns. Whether speculation will do so depends not only on whether markets are competitive and are characterized by good information but also on whether or not land owners are able to internalize all of the benefits from reserving land for future use. This is illustrated by the two cases discussed earlier in this paper in which discontinuous development is efficient. In the first of the two examples worked out above, where there are two different densities of development but no commercial enterprises, the model is set up in such a way that all of the benefits from temporarily holding land vacant are internalized by the speculator-developer. And it can be shown in this case that a well-functioning private speculative land market will indeed lead to efficient allocation.[7] However, in the second of the two

[7] This result is proved, using a simple linear programming model, in a working paper by the authors, "Discontinuous Urban Development and Economic Efficiency" (May 1974), available from the authors upon request.

cases discussed above, where one of the competing land uses is a commercial center, private speculation may not be efficient in allocating the land. The basic reason for this is that (assuming the shopping center cannot price discriminate between customers coming from different distances) it is not possible for the owner of the land in this case to completely internalize all of the social benefits which accrue from reserving the land for future development. *Some* of these benefits may be internalized. For instance, it could be shown in an expanded example that a more central shopping location may lead to higher profits for the developer. Hence there may be some tendency, even in this case, for private speculation to reserve land for future use. At the margin, however, the store owner will not be able to internalize all of the consumers' savings in transportation costs resulting from the central location, and hence at the margin private sector speculation may not produce an economically efficient resource allocation. Essentially, in this case there are consumers' surplus gains from the lower transportations costs which do not accrue completely to the speculator-developer, and as a result private speculative markets may not yield efficient decision making.

In summary, then, high speculative prices do not necessarily distort sound economic decision making. Furthermore, even if the speculative prices arise in uncoordinated competitive markets, this lack of non-price coordination need not make the final market outcome inefficient. Indeed, if markets are competitive and if speculator-developers are in a position to internalize the benefits of their speculative activities, then speculation, rather than *distorting* efficiency, will be the market process which *ensures* efficient resource allocation. Contrary to the conventional wisdom, high prices of land which result from speculative demand and which prevent development at relatively early stages of growth are not necessarily an indication of misallocation of resources.

CONCLUSIONS

This paper has presented reasons for believing that discontinuous urban development may often be consistent with efficient allocation of resources. In particular, we have discussed in some detail two possible cases where discontinuous development patterns may represent efficient allocations of land in the urban setting. In the first case, it was shown that in the context of the expansion of a rapidly growing city it may sometimes be efficient to skip over relatively centrally located land early in the development process in order to build low-density dwellings in suburban locations. The skipped-over land is then filled in with higher-density residential buildings during later stages of development.

The second urban development scenario discussed in the paper concerned the development of a commercial center near the fringe of an urban area. Here too it was shown that under some conditions it is efficient temporarily to skip over developable land. The vacant land is then filled in with commercial development after population in the area has grown sufficiently to allow an efficient scale of operation for the commercial activity.

Nothing in our discussion shows that *all* cases of discontinuous development reflect efficient market processes. Indeed, while it was not our purpose to discuss them in this paper, we believe that there may well be a variety of institutional forces in the market including possible monopoly elements and inefficient tax incentives which work against land market efficiency in some urban contexts. However, what we hope that the above analysis *does* suggest is that competitive urban land markets may well allocate land more efficiently than many observers seem to believe.

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