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AN EVALUATION OF THE IMPACT OF GROWTH ON THE URBAN FRINGE USING TWO METHODS OF ESTIMATING PUBLIC SERVICE COSTS

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Introduction

Agricultural land use in rural-urban fringe areas has received strong competition from expanding urban communities during recent years. Urban growth has resulted in the removal of many acres of prime agricultural land from production. At the same time rapid growth on the urban fringe has degraded the very environmental attributes that initially provided the attraction to urban dwellers. These difficulties have arisen from the operation of the private land market which fails to fully account for the social costs of land-use transitions. Urban planners and public officials have sought to minimize these external impacts on the land market through zoning and other restrictions on land use. However, these attempts have been relatively ineffective due to a lack of necessary social cost information, the misassignment of public service costs, and analytical models capable of evaluating the impacts of various mixes of land uses.

The purpose of this paper is to describe the differences in normative growth patterns and associated financial impacts that would result from using two alternative approaches to estimate municipal costs. A recursive programming model was used as the optimizing framework.

The Model

A recursive programming model was used to determine normative land use patterns over time, subject to a set of constraints. Development was initiated by a population growth factor and the model was required to create housing according to a preference mix. It was assumed, however, that the households would be indifferent with respect to location in different density zones.

The objective functions in the model were linear functions of alternative rural and urban uses for fringe land. These functions measured the net contribution to, or imposition on, the community's revenues from each land-use alternative. Four major types of land uses--residential, publicly owned outdoor space, productive rural and "other" rural uses--were included in the model. Additional land uses, such as commercial and industrial uses, were omitted from the model because they used relatively little land in the case study township and evidence suggests that they use relatively little land in most rapidly growing urban communities.

The residential activities included a group of four, different-valued, single-family homes--$15,000, $22,500, $30,000 and $42,500. Apartments were represented by three building sizes typical of the case-study township--four-family, eight-family and sixteen-family buildings. These multifamily buildings were categorized into three classes based on the value of individual dwelling units--$8,000, $11,500 and $15,000 per unit.

Publicly owned open space was categorized into two classes--(1) playground areas and (2) hiking and picnicking areas. Playground areas were defined as public land located in a residential area containing a large open area on which outdoor recreation activities is allowed. Hiking and picnicking areas were defined as publicly owned areas for observing and being a part of natural surroundings, generally located in wooded and hilly areas or along the edges of streams and ponds in conservation areas purchased by the township.

The predominant productive rural uses in the township were dairy farms and apple orchards. Activities representing each of these land uses were included in the objective functions. The other "rural uses" activities primarily represented abandoned fields in various stages of natural regrowth.

All land was zoned for residential use by the township. Two zones were characterized by two different minimum lot sizes for single-family dwellings--the R-O zone with a 30,000 sq. ft. minimum and the R-N zone with a 20,000 sq. ft. minimum. Construction of apartment buildings was only allowed in the R-N zone. In addition, in the AAC analysis (described below) the land in each of these zones was coded by a 1, 2 or 3, written as R-O-1, R-O-2, R-N-3, etc. These additional codes classed the land by the public service facilities, specifically water and/or sewer mains, available to it at the beginning of the study period. Class 1 land (R-O-1 and R-N-1) had sewer and water mains; Class 2 (R-O-2 and R-N-2) had water mains but not sewer mains; Class 3 land (R-O-3 and R-N-3) had neither water nor sewer mains at the time of the study.

A forecasting horizon of twenty years was selected for study and divided into four periods of five years each. During each of these five-year periods the objective was to maximize the net revenue, i.e., the total tax revenue minus public service costs, received from various land-use mixes by the township as the town's population increased and land was shifted from rural into residential uses. Certain environmental quality, land and other constraints were placed on the maximization function, as described below.

Five constraint categories were used in the model. Land constraints were used to limit the amount of land used in either the R-O zone or the R-N zone for each time period. Public service constraints limited use during each period to the excess capacity of public service facilities existing at the beginning of the period. If needed, provision was made in the model for purchase of additional capacity through investment. A series of housing constraints was used as a demand proxy to insure that a reasonable mix of alternative types of housing and the proper amount of housing was provided to absorb the population increase in each time period. A pair of recreation land constraints insured that adequate playground space and hiking and picnicking space were also provided. Finally, a series of four environmental quality constraints were used to assess the relative environmental impacts of the various land uses and to control environmental degradation.

These constraints were labeled density, openness, visual quality and closeness to nature. Density was a measure of the population density per acre of each of the land-use activities competing for fringe land. Openness was a measure of the proportion of land not under buildings for each of the land-use alternatives. Visual quality was a measure of the pleasantness of the visual experience afforded by each land-use alternative, where pleasantness was defined in terms of visual variety and order. Closeness to nature was a measure of the naturalness of each land-use activity, determined by the relative degree of closeness to the natural state and the availability of the land to the public. These environmental quality constraints do not account for all aspects of environmental quality, but they were not intended to. The major concern here was man's impacts on open space and the visual amenities which land could offer depending on its use.

Coefficients (C_j's) for each of the alternative land-use activities in the objective function represented the net revenue, in 1970 dollars, contributed to the township by a newly converted acre of land of each respective land use. Net revenue was defined as total tax revenues generated by an acre of land in its new use minus the costs of public services for that acre of land in its new use.

The costs associated with individual land uses were estimated by two different methods. The first, called "Conventional Average Costs" (CAC), represented the method normally used in research studies and by local governments to estimate the financial impact of additional housing on a town, i.e., the total cost of providing public services during the base year were divided by the number of existing dwelling units in the community to calculate the average cost per dwelling unit.

The second method, called "Adjusted Average Costs" (AAC), more closely represented the actual financial impact of additional housing on the township when public service costs associated with the incremental population were assigned only to land used by this incoming population and the amounts of public service facility excess capacities were taken into account. While this procedure did not truly represent marginal costs, as would have been most desirable, it did allocate costs more closely to their actual incidence than the CAC approach, and did so in a manner which was more easily calculated than marginal costs.

The total tax revenue for an acre of land in the same use was identical for both approaches, but the net revenues (C_j's) differed because of the differences in the costs per acre for public services. The difference in results from using these two different cost-estimation techniques is described in the following section.

Optimal Solutions

CAC Solution

Throughout the four time periods, all single-family homes were located in the R-0 zone[1/] (see Table 1). A total of 1,299 acres was converted to single-family home use during the twenty-year period. There were 318 acres for 369 single-family homes of $15,000 value, 276 acres for 321 homes of $22,500 value, 429 acres for 498 homes of $30,000 value and 276 acres for 321 homes of $42,500 value. Additional acreage was converted to residential use as apartment buildings--440 acres during the twenty-year period. Ninety acres were used for four-family buildings, 191 acres for eight-family buildings, and 159 acres for sixteen-family buildings. Playgrounds accounted for a total of 85 acres during the twenty-year period. Total urban use in the CAC solution was 1,824 acres. This left 5,377 acres for agricultural use at the end of the twenty-year period. All of this land was placed in the dairy farm use category in this solution.

In addition to the land described above, 174 acres of conservation land used specifically for hiking and picnicking purposes was added to the town's public holdings.

Table 1

A Comparison of Optimal Land Use Patterns Under
Two Alternative Methods of Estimating Financial Impact

Land Use Category		CAC Solution[a/] R-O Zone[c/] (acres)	CAC Solution[a/] R-N Zone[d/] (acres)	AAC Solution[b/] R-O Zone[c/] (acres)	AAC Solution[b/] R-N Zone[d/] (acres)
Single Family Homes:	$15,000 Average Value	318	Nil	3	211
	$22,500 Average Value	276	Nil	Nil	185
	$30,000 Average Value	429	Nil	Nil	285
	$42,500 Average Value	276	Nil	49	152
	Subtotal	1,299	0	52	833
Apartment Dwellings:	4 Family	Nil	90	Nil	87
	8 Family	Nil	191	Nil	191
	16 Family	Nil	159	Nil	158
	Subtotal	0	440	0	436
	Total Land Developed	1,299	440	52	1,269
Public Uses:	Playgrounds	85		84	
	Hiking, Picnicking, etc.	174		174	
Agricultural Uses:	Dairy	3,246	2,131	4,522	1,273
	Orchards	Nil	Nil	Nil	Nil
	Other Rural Uses	Nil	Nil	Nil	Nil
	Subtotal	3,246	2,131	4,522	1,273

a/ CAC - A method in which average cost per existing dwelling unit for municipal services is used to assess impact of additional dwelling units.

b/ AAC - A method in which an attempt is made to assess impact of growth through estimates of the marginal municipal service costs associated with additional dwelling units.

c/ R-O zoned land is designated as residential with minimum lot size of 30,000 sq. ft. for single-family homes. The greater portion of this land is not served by municipal water or sewerage.

d/ R-N zoned land is designated as residential with minimum lot size of 20,000 sq. ft. for single-family homes. The greater portion of this land is served by municipal water and sewerage.

AAC Solution

In the AAC analysis, most single-family homes were located in the R-N zone. Only during the third time period, when all the R-N-1 zoned land had been used up were any single-family homes located in the R-O zone. A total of 885 acres of land was converted to single-family home use in the AAC solution. Two hundred fourteen acres were used for $15,000 homes (369 dwelling units), 185 acres for $22,500 homes (321 dwelling units), 285 acres for $30,000 homes (498 dwelling units) and 201 acres for $42,500 homes (321 dwelling units). For apartment buildings, 436 acres were needed during the entire time period--87 acres for four-family buildings, 191 acres for eight-family buildings and 158 acres for sixteen-family buildings. In addition to these residential uses, 84 acres were converted to urban use as playgrounds. Summing these acreages yields a total urban land conversion of 1,405 acres, some 419 acres less than the amount of land converted to urban use in the CAC solution. This left 5,795 acres in agricultural use, all of which was in dairy farms.

The same amount of land, 174 acres, was converted to hiking and picnicking usage in the AAC solution as in the CAC solution.

Monetary Impacts

The total net revenue from the CAC solutions was negative in all four time periods. There was a total net revenue to the town of -$593,037, i.e., a net cost, over the twenty-year time period.

The monetary impacts in the AAC solutions were positive in each period and contributed net revenues of $332,449 to the town treasury over the same twenty-year period.

Non-Monetary Impacts

In each period and for the entire twenty-year period, more quality units[2/] were used by the urban sector in the CAC analysis than in the AAC analysis for each of the environmental constraints. The results are as follows:

(1)	density index	--	CAC - 4,355 units
			AAC - 4,346 units
(2)	openness index	--	CAC - 4,643 units
			AAC - 4,092 units
(3)	visual quality index	--	CAC - 3,437 units
			AAC - 2,682 units
(4)	closeness to nature index	--	CAC - 6,586 units
			AAC - 5,126 units

These results indicated that a greater degree of environmental degradation was associated with the CAC solution than the AAC solution.

Conclusions

CAC Versus AAC Analyses

Although most of the input data was the same for both the CAC and AAC analyses, there were distinctive differences in the way public service costs were assigned to land-use activities. These differences resulted in a noticeable disparity between the results of the two analyses, e.g., differences in the land-use activities which were optimal, differences in the magnitude of environmental impacts and differences in the monetary impacts.

The implications of these results are highly significant for municipal officials and a town's growth pattern. If officials base decisions about the monetary and environmental impacts of new housing on a town using the CAC method, they will discourage apartments and encourage expensive single-family homes on large lots dispersed on the outskirts of town. In the CAC analysis, costs are assigned equally to each dwelling unit throughout the town and it appears to be less expensive to minimize the density of housing by encouraging single-family housing on large lots. However, this cost-estimation method ignores the large increases in costs which result when servicing new homes requires construction of new public service facilities such as a sewage treatment plant or extended water or sewer mains, and it ignores the environmental impacts of dispersed settlement. Conversely, information about savings involved when new residences use existing facility capacity is also ignored.

If, instead, decisions were based on an AAC type of analysis, this additional information would be included and the resulting normative solution as to types and location of residences would be considerably different. Placement of single-family homes on smaller lots close to the existing urban centers, especially where municipal services were already available, would be encouraged. More expensive homes would be favored by the town over less expensive homes, but the less expensive homes would not necessarily be seen as a financial burden on the town finances. Also, apartments would be encouraged, rather than discouraged, as a financially viable means of housing people while sacrificing less open space.

In addition, this method of estimating costs tends to promote more variety of housing types in a town, which may, in its own right, create positive amenities for the community from the increased visual variety. Most persuasive, however, is the vast difference in the financial picture after twenty years of growth. While housing the same number of people, the CAC solution indicated a twenty-year net loss of $593,037 when, for the same time period, the AAC solution indicated a net gain of $332,449.[3/]

Representativeness of Results

The analyses in this study were based on data from one case-study town in Western Massachusetts. Thus, the findings cannot make a claim for universal application. They do inherently make sense, however, and provide the basis for making strong hypotheses about residential expansion in rural-urban fringe areas. These hypotheses are: (1) community officials will be more effective in planning if they consider the actual costs imposed on the town by new residences, (2) a more desirable community, from both financial and environmental standpoints, will be achieved by encouraging a mixture of apartment buildings and single-family homes in the community than if only one or the other are allowed, (3) new residences in a community will make a positive net dollar contribution to the community if substantial excess capacity exists in a majority of the municipal services, and (4) additional population growth will be extremely expensive for a community if most of its service facilities are being used to capacity.

Recommendations for Further Research

Additional studies are needed to apply models which combine both market-measurable and external effects to the process of planning land use in rural-urban fringe areas.

While simultaneously measuring market-measurable and external effects of changes in urban fringe land use is the end goal, more work is needed to learn how to appropriately measure the external effects themselves. The single, largest handicap for this study was the absence of generally recognized measures of the environmental quality impacts of the land uses under analysis, either in absolute or in relative terms.

Footnotes

1/ The three R-O zones all had in common the 30,000 square feet minimum residential lot size.

2/ "Quality units" were the basic unit of measure for the environmental quality constraints and simply served to monitor the impact on the environmental characteristics identified. At the beginning of the twenty-year period the township was allotted 28,792 quality units for each environmental quality constraint. Through time, if land conversion took place and the environmental amenities of the township were reduced, these quality units were used up--greater rates of use indicating greater degradation.

3/ In reality, of course, a net loss is impossible since the township does not function in terms of profit or loss. What these data do indicate are relative differences in municipal costs which would translate to the impact on the relative property tax burdens of alternative development patterns.