regional shopping centers in Latin America in addition to the obvious factors of consumer expenditures, automobile availability, site constraints and financing.

The development of shopping centers with three major anchors is not foreseen in the immediate future. Instead the continued expansion of two-anchor shopping centers will occur, but not at a rapid pace. The key growth elements will be discounting and a general proliferation of high density, multi-use projects of which retail uses will generally occupy less than 100,000 square feet contained in many relatively small stores. Through 1983 it is expected that no more than a dozen regional centers will exist in Latin America, and then only in selected metropolitan areas exhibiting high incidences of population, income and automobile growth—principally Mexico City, São Paulo and Caracas. It can convincingly be argued in fact that multi-use projects with relatively small concentrations of retail use will provide a more logical means of capturing increased consumer expenditures in Latin America, maximize developer profits, and be more compatible with development trends. This implies then that regional center development will be largely dependent upon the aggressiveness of major department store chains, increasing sophistication of developers, and a move to a longer-range outlook on the part of the principals involved in real estate projects.

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Evidence on Erosion of a Resource Due to Population Growth: Case of the Public Library

The modern theory of public expenditure has historically focused on determining the optimal supply of goods and services to be provided by the public sector with less attention devoted to developing rules and procedures concerning their use. Once the public good is supplied, however, persons and institutions acting individually without restrictions may erode its economic value by producing what James Buchanan calls "public bads."[1] In order to avoid this erosion a complete theory of the public sector involves problems of efficient use of the good, service or facility as well as the appropriate expenditure. According to Buchanan, the conservation of private property can normally be trusted to the workings of the market but the conservation of public property requires explicit public policy.[2]

Examples of this erosion process can readily be found in the land resources supplied by the public sector for recreation. Krutilla and Knetsch note the ecological damage done by an even greater number of visitors to Yosemite, the Grand Canyon's south rim and the geothermal sights of Yellowstone.[3] Such over-utilization threatens the long-run survival of the resource and explicit restrictions limiting use are required for their conservation. The usual economic solution is to restrict entry by fees in order to limit demand to the optimal number of users. Unfortunately for outdoor recreational facilities dollar values for marginal benefits and marginal costs cannot readily be determined because of the nonmarket character of both benefits and costs. The optimal number of visitors in an economic sense is difficult to calculate and a "rule-of-thumb" approach might be more suitable. In the above examples of intensive use, "capacity" could be defined as the ecological danger point where the long-run existence of the resource is jeopardized with user fees then set to limit the number of visitors during any time period to capacity.

Another example of the production of "public bads" in the natural resource area concerns the current essentially free entry into the lobster industry. Frederick Bell has empirically tested a model showing a decline in the steady-state lobster catch along the northeastern coast when the number of traps set exceeds a certain limit thus leading to adverse effects on the growth of the species.[4] Due to the absence of a carefully developed plan for the exploitation of this common-property resource, Bell shows that the industry literally destroys itself through overinvestment as the price of lobster increases. A non-optimal but perhaps workable solution would be to permit entry as long as there is an increase in the long-run sustainable yield.

The absence of adequate public policy in the use of highways also leads to individual behavior producing "public bads." A. A. Walters' model of traffic congestion shows that the number of cars flowing off a highway increases as the number of entrants increases but declines after the number of entering cars exceeds a certain level.[5] A "rule-of-thumb" approach for public facilities, such as highways, is to allow the number of users to increase as long as total output is also increasing. When total output measured in some economically meaningful sense falls, such as vehicles-per-hour in the Walters example, with an additional user then the "capacity" is reached and further admission should be restricted.

This paper develops a model of library use which demonstrates that continued population growth in the area served leads to an erosion in the stock of books and eventually diminishes rather than increases total circulation. In this case a "rule-of-thumb" solution to library membership might be set at the point where additional members cause

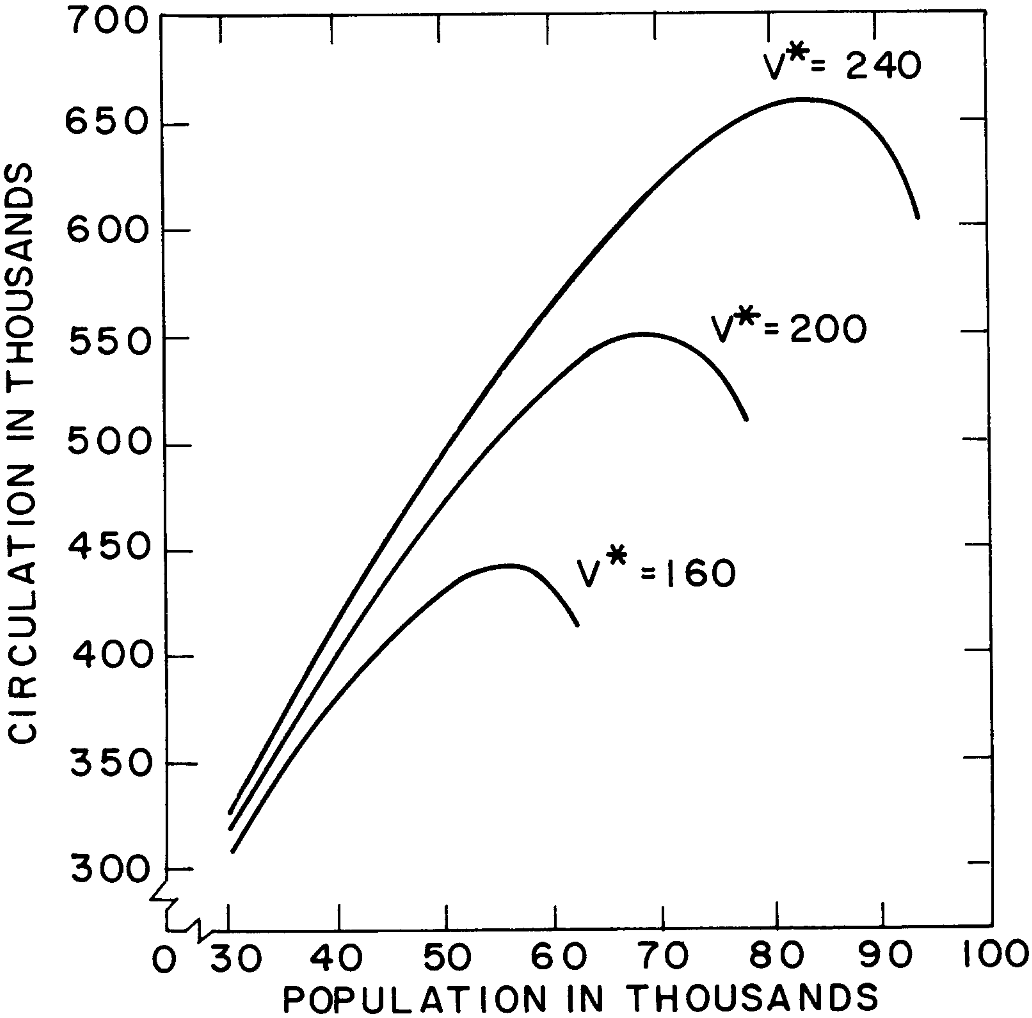

FIGURE 1—Total Circulation as Population Increases, Given Target Stocks of 160, 200 and 240 Thousand Volumes

circulation to decline. Further population growth can create a situation where the rate of loss through use exceeds the rate of addition through purchase. The library's capital stock is thus eroded and endangered in a manner analogous to the threatened destruction of the resource stock of recreational areas. The public library experience can be extended to other facilities in the public sector, such as housing developments and educational institutions, where concern with an adequate expansion of supply has led to a lack of policy regarding use. This situation may lead to an erosion of facilities and a reduction in the value of their services producing the common complaint about the decline in the quality of public services despite rising expenditures and taxation.[6]

A Model of Library Use

During each time period volumes are added to the stock of books through purchase decisions but the stock is reduced as volumes are lost, misplaced, misshelved, stolen or never returned. The steady-state stock depends on the rate of addition by purchase and the rate of loss. In order to estimate the number of volumes added through purchase we assume that without losses imposed by use, the stock of books would increase following the logistic growth curve

$$(1)\quad V_t = \frac{V^*}{1 + be^{-gt}}$$

where V_t = volumes on hand at time t, V^* = the target stock of volumes set as the long-run goal for the library, and b and g are parameters. Differentiating (1) with respect to t yields an addition to the stock arising from purchase of

$$(2)\quad \frac{dV}{dt} = g(V^* - V_t)\frac{V_t}{V^*}$$

Though the above logistic curve was used by Bell as part of a biological growth model, the decision rule suggested by (2) seems to make sense intuitively when applied to the growth of a library's stock through purchase.[7] When the number of books on hand V_t is low the difference between the target V^* and V_t is great but only a relatively small fraction, V_t/V^* of $V^* - V_t$, can be ordered. When the library is near capacity $V^* - V_t$ is small but a large fraction of this difference can be purchased. While (2) is the increment to the stock through purchase during t there is a decline due to losses arising from use. This reduction is assumed to be proportional to the size of the population M_t served by the library and is written as θM_t. Subtracting θM_t from equation (2) allows the net change in the number of volumes on hand for time period t to be written as

$$(3)\quad \frac{dV}{dt} = g(V^* - V_t)\frac{V_t}{V^*} - \theta M_t$$

The output of the library during a specified time period, as measured by total circulation, should be proportional to (1) the size of the community served, (2) the educational level of the population, and (3) the quality of the library. Denoting E_t as the educational level and measuring library quality as V_t/V^*, the number of volumes on hand as a fraction of the target number, suggests a total circulation function C_t of the form

$$(4)\quad C_t = \beta\, E_t\, M_t \frac{V_t}{V^*}$$

where β is the proportionality constant.

Equations (3) and (4) comprise the model describing the relationship of population size to the stock of books and total circulation. The steady-state solution to the stock of books can be found by setting $dV/dt = 0$ or where the addition to the stock through purchase exactly offsets the erosion due to population pressure. Setting (3) to zero yields an expression relating the target stock V^* to the steady-state stock V_t of

$$(5)\quad V^* = \frac{V_t^2}{V_t - \dfrac{\theta M_t}{g}}$$

Substituting V^* into the circulation equation (4) produces an equation of circulation per capita, C_t/M_t, that can be written as

$$(6)\quad \frac{C_t}{M_t} = \beta\, E_t - \beta\frac{\theta}{g} E_t \frac{M_t}{V_t}$$

Equation (6) says that the steady-state circulation per capita is an increasing function of the community's educational level E_t and a decreasing function of an intersecting term, M_t/V_t, the number of people in the community for each book on hand at the library. The coefficient of E_t should therefore be positive and $E_t(M_t/V_t)$ is expected to have a coefficient with a negative sign.

Empirical Test of the Model

The parameters of the model θ/g and β are estimated for the years 1951, 1961 and 1971 from equation (6) using cross-sectional data. Data were collected for those libraries in Massachusetts serving city populations of between 20,000 and 120,000 people. The sample attempts to include libraries characterized as medium-sized with similar services, costs, and delivery systems.[8] Hence rural libraries and those located in large, high-density urban areas were excluded since no attempt is made to build into the model variables to describe the special characteristics of systems located within sparsely populated areas or those operating multi-branch facilities within major cities.

Information on circulation C_t and volumes V_t for 1951, 1961 and 1971 was obtained from annual reports of the Massachusetts Board of Library Commissioners.[9] Population data M_t is estimated as the population reported in the census years 1950, 1960 and 1970.[10] The educational level of the community, E_t, is measured as the percentage of adults over the age of 25 finishing high school as reported in the above census years. Applying ordinary least squares to estimate circulation per capita from (6) yields the following results (figures in parentheses are t-statistics):

$$1951 \quad \frac{C_t}{M_t} = \underset{(1.9)}{1.69} + \underset{(6.6)}{.127\,E_t} - \underset{(-2.6)}{.096\,E_t}\frac{M_t}{V_t}$$

$R^2 = .65$
obs. = 44

$$1961 \quad \frac{C_t}{M_t} = \underset{(1.1)}{1.20} + \underset{(7.9)}{.173\,E_t} - \underset{(-3.0)}{.128\,E_t}\frac{M_t}{V_t}$$

$R^2 = .71$
obs. = 47

$$1971 \quad \frac{C_t}{M_t} = \underset{(-1.1)}{-1.11} + \underset{(11.0)}{.168\,E_t} - \underset{(-6.5)}{.106\,E_t}\frac{M_t}{V_t}$$

$R^2 = .74$
obs. = 64

In each year the coefficients of E_t and $E_t(M_t/V_t)$ have the expected signs and are statistically significant at the 5 percent level or better. The model did not include a constant and the results support this formulation since the constant term is statistically insignificant at the 5 percent level in each case though barely so for 1951. The parameter β of the model is directly given from (6) as the coefficient of E_t in the regression equation. The parameter θ/g is not found directly but the coefficient of $E_t(M_t/V_t)$ is $\beta(\theta/g)$. Using the results for β an estimate of θ/g can be made since θ/g is simply the regression coefficient of $E_t(M_t/V_t)$ divided by β. The model's parameters for each year have the following values:

1951	$\beta = .127$	$\theta/g = .756$
1961	$\beta = .173$	$\theta/g = .739$
1971	$\beta = .168$	$\theta/g = .634$

As an illustration of the effects of population growth on a library system the estimates of β and θ/g for 1971 will be used to relate total circulation C_t and population M_t. Setting equation (3) to zero yields a steady-state stock of books V_t equal to

$$(7) \quad V_t = \frac{V^* + \sqrt{(V^*)^2 - 4\frac{\theta}{g}M_t V^*}}{2}$$

recalling that V^* is the target the community has set for the library's stock.[11] Substituting this expression into (6) total circulation can be expressed as a function of population as

$$(8) \quad C_t = \beta E_t M_t - \frac{2\beta\frac{\theta}{g}E_t M_t^2}{V^* + \sqrt{(V^*)^2 - 4\frac{\theta}{g}M_t V^*}}$$

Table I shows the results of calculations of total circulation made using equation (8) as population increases with 1971 values of $\beta = .168$ and $\theta/g = .639$. The educational level E_t is fixed at 70% of the population over the age of 25 finishing high school or $E_t = 70$. Total circulation is presented for target library stocks V^* of 160,200 and 240,000 volumes with population M_t varied selectively within the intersecting range for each target. Note that as population grows,

TABLE I—ESTIMATED CIRCULATION AND THE STEADY-STATE STOCK OF BOOKS*

Population	Circulation (Vols/Yr)	Steady-State Stock (Vols)
Target = 160,000 Volumes		
40,000	377,600	128,400
44,000	401,200	124,000
48,000	420,500	119,000
52,000	434,200	113,500
56,000	440,000	106,800
60,000	431,300	97,700
*62,000	—	0
Target = 200,000 Volumes		
50,000	472,000	160,500
54,000	496,000	156,000
58,000	516,700	151,400
62,000	533,400	146,200
66,000	545,100	140,400
70,000	550,000	133,500
74,000	543,600	124,800
78,000	507,500	110,600
*80,000	—	0
Target = 240,000 Volumes		
70,000	622,000	181,200
74,000	638,000	176,000
78,000	651,300	170,300
82,000	658,700	163,800
86,000	658,900	156,300
90,000	646,900	146,600
94,000	599,300	130,000
*96,000	—	0

Given $\beta = .168$, $\theta/g = .634$, $E_t = 70$ and V Targets of 160, 200 and 240 Thousand Volumes.

total circulation also rises at first but the increment becomes less and less due to the decline in the steady-state stock of books.

Population pressure, in a sense, erodes the resource and as it continues growing, circulation reaches a maximum and then starts falling. The positive contribution of a greater number of users to total circulation is offset by the negative effects of a decline in the steady-state number of volumes on hand. Capacity in terms of users could be defined as the population level maximizing circulation. Finally, population pressure becomes so intense that no real steady-state stock is possible and the resource is ultimately destroyed. This critical point is indicated in Table I by an asterisk and corresponds to a population level where, from equation (7), $M_t > 4(g/\theta)V^*$. Figure 1 sketches the full relationship between population and circulation partly tabulated in Table I and clearly illustrates the eventual negative effect of increased population size on total circulation. The critical population size threatening the long-run viability of the library is just beyond the highest population value plotted for each target stock of books. The capacity of the resource might be understood in Figure 1 as that population size producing the peak circulation.

Implications

This paper has demonstrated that population growth can lead to a decline in the output obtained from a resource and finally, after a certain point, to an end to the resource's economic usefulness. A model of erosion has been applied and successfully tested for a library system though policy implications are important to other goods and services provided by the public sector, particularly those concerning land resources. An increase in population can erode natural resources and deteriorate public facilities as well as reduce library volumes. The rate of recuperation of a natural resource such as park land or the annual maintenance expense for the public facility is analogous to the purchase of additional volumes by the library. At some point an increase in the number of users will cause a decline in the annual economic output of a public sector resource just as it leads to a decline in circulation at the library. As a "rule-of-thumb" for public policy, the number of users could be restricted in order to avoid this inefficient stage of operation. At some further point along the path of population growth is the eventual destruction of the resource just as the library's stock of books is eventually destroyed when the annual erosion due to use exceeds additions through purchase.

Evaluations of current policies toward the use of public sector resources should therefore not necessarily associate an expansion in the number of users with an increase in economic benefit. Public administrators should also be alert to the danger associated with a growth in use since erosion may reduce the economic value of the resource or even threaten its survival.[12] Policies ignoring conservation by permitting continued unrestricted entry or entry at nominal cost cannot be defended as being in the short-run or long-run public interest. The case for limiting the number of users is particularly strong for land resources due to their unique character. In the library case eventual destruction of the resource through erosion caused by population pressure could be averted by raising V*, the target stock of books, but in the natural resource situation an increase in the target stock of these facilities may be, as in the case of wilderness areas, fishing grounds, redwood forests, sand dune waterfront and other common-property resources, literally impossible. In other public sector concerns, such as housing, transit, education, or the arts, resources could be maintained by increased expenditures but without appropriate rules concerning use, individualistic choice produces "public bads" and the additional expenditures will yield a disappointing increment to social welfare.

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FOOTNOTES

[1] James M. Buchanan, "Public Goods and Public Bads," in John P. Crecine (ed.), *Financing the Metropolis* (Beverley Hills: Sage Publications, 1970), pp. 51–56.

[2] *Ibid.*, p. 69.

[3] John Krutilla and Jack Knetsch, "Outdoor Recreation Economics," *Annals of the American Academy of Political and Social Science,* May 1970, pp. 63–70.

[4] Frederick Bell, "Technological Externalities and Common-Property Resources," *Journal of Political Economy,* January 1972, pp. 148–158.

[5] A. A. Walters, "The Theory and Measurement of Private and Social Cost of Highway Congestion." *Econometrica,* October 1961, pp. 676–699.

[6] For a further analysis of the need, in some cases, for bureaucratic organizations to constrain individualistic choice see, Vincent Ostrom, *The Intellectual Crisis in American Public Administration* (University, Alabama: University of Alabama Press, 1973), pp. 56–73.

[7] Bell, *op. cit.*, p. 149.

[8] See H. W. Winger, "Characteristics of the Medium Size Public Library," in Leon Carnovsky and Howard Winger (eds.), *The Medium Sized Public Library: Its Status and Future* (Chicago: University of Chicago Press, 1963).

[9] Massachusetts Board of Library Commissioners, *Annual Reports,* Boston, 1951–1971.

[10] U.S. Bureau of the Census, *Census of Population. General Social and Economic Characteristics,* Washington, D.C., Government Printing Office, 1950–1970.

[11] Only the positive sign for the square-root term is relevant since it yields $V_t = V^*$ when $M_t = 0$ and results in the desired relationship $dV_t/dM_t < 0$ implying a decline in the steady-state stock with increased population.

[12] Unfortunately, current traditions in public administration regarding efficiency may lead administrators to overlook the underlying causes of the problem and thus fail to develop constructive proposals. See Ostrom, *op. cit.*, pp. 33–47 and pp. 124–129.

Position in the Urban Hierarchy as a Determinant of In-Migration†

THIS PAPER SEEKS to demonstrate that a city's position in the urban hierarchy will affect the response of in-migrants to that city's growth in municipal expenditures and manufacturing employment. This fact has important policy implications. Knowledge of a city's position in the hierarchy is shown to be necessary to correctly evaluate the effect of a government policy to either discourage or encourage growth. Empirical evidence was obtained from urban areas in Central Canada: the provinces of Ontario and Quebec. Since urban areas in Central Canada differ in their position in the hierarchy, a uniform federal policy will not result in a uniform response. This is especially true for a policy of developing new towns. If the government wants to divert urban growth from a large central city to a satellite city, the corresponding policy must take into account the position of the selected new town in the urban system hierarchy.

The Model

The model set up for this study is a reduced form equation incorporating both supply and demand factors generating metropolitan growth. Implicitly, two structural equations generating urban growth underlie the model. One is the export-base approach and the other is the infrastructure approach to urban growth. The export-base