Pergamon

Comput., Environ. and Urban Systems, Vol. 19, No. 5/6, pp. 409–417, 1996

0198-9715/95$9.50 + 0.00

S0198-9715(95)00022-4

MANAGING PROBATION PROGRAMS WITH GEOGRAPHIC INFORMATION SYSTEMS

Jay Lee[1]

Department of Geography, Kent State University, Kent, Ohio 44242-0001, U.S.A.

ABSTRACT. *At a time when funding for probation does not catch up with the growth in caseloads, probation programs need to adopt new technology, such as geographic information systems (GIS), to increase their management efficiency. We discuss our implementation of a GIS to support management of the probation program in Cuyahoga County, Ohio. GIS provides a set of efficient tools for data integration, mapping, and analysis. Furthermore, it allows probation officers to understand their clients and plan their tasks better. As a decision support system, GIS integrates information from various sources and makes them readily available to probation officers. As a data analysis tool, GIS enables probation officers to study the profiles of their clients with only minimal efforts. As a task management assistant, GIS supports a wide variety of alternatives in storing or updating records and planning activities.* Copyright ©1996 Elsevier Science Ltd.

INTRODUCTION

In most cases, probationers were first-time offenders or minor offenders, and they received probation terms as acts of judicial leniency allowing them to remain in the community despite their crime (Clear & Braga, 1995). Since 1980, there have been significant growth in probation caseloads similar to the growth seen in prison population (Langan, 1994). Today, three out of every four offenders under correctional control are supervised in the community by the form of probation (Dillingham, 1990). Even though community corrections absorbed a greater increase in offenders than did the prisons during the 1980s, it was the prison budget that grew (Clear & Braga, 1995).

Funding to state and local prisons has doubled between the 1970s and the 1990s, but funding has remained constant for probation during the same period [estimated by Langan (1994)]. Therefore, community supervision has been a somewhat elastic resource that is forced to accept whatever numbers of offenders the system requires it to handle. Some studies indicate that the average probation or parole officer carrying a large caseload can make between 90 and 120 face-to-face contacts in a month (Bemus & Baird, 1988). However, today's reduced funding for probation resulted in caseloads routinely in excess of 150 probationers, often as high as 300 or more for one probation officer (Banks et al., 1977; Cunniff & Shilton, 1991).

Reduced budget in correctional programs led to a surge of interest in the development of a more effective method of structuring correctional supervision. Under current low levels of funding, it is apparent that probation programs need to improve their efficiency if it is not

[1] Tel: 216-672-3222; Fax: 216-672-4304; e-mail: lee@humboldt.kent.edu

possible to increase financial resources. Conventional tools, such as database management systems (DBMS), provide only very limited assistance to probation management because of their inability to handle geographic components existing in probationers' records. Probation programs need to be managed with different foci between different environments. Probation officers need tools that assist them in an integrated setting.

Geographic information systems (GIS) have emerged in recent years as an efficient tool for information management and decision support system. GIS allows users to enter, manipulate, analyze, and display geographic information. A GIS can be used by probation officers to monitor clients on probation to fulfill the requirements imposed by judges. These requirements typically include close monitoring of clients with regards to their changes of addresses and home visitations. Moreover, a GIS will assist probation officers in planning visitation routes and alerting officers of the locations of clients relative to risk areas such as schoolyards and known high crime areas. Consequently the results of using GIS are extremely valuable to county courts, probation and police officials as a reference for future additional police, educational efforts or planning crime prevention in respective community.

In this paper, we describe our implementation of a GIS for probation management. Funded by the Urban Universities Program of the Ohio Board of Regents, we use a data set provided by the Court of Common Pleas, Probation Department of Cuyahoga County of Ohio. This data set includes educational background, residential stability, economical status, types of charges, past criminal records, and social contacts for individuals who are placed on intensive probation. Although the data set used in this project is from Cuyahoga County, Ohio, one can easily expand the applicability of the resultant GIS model to other urban communities across the nation.

A GIS FOR PROBATION MANAGEMENT

Besides face-to-face contacts with probation clients, the tasks of a probation officer may be classified into three general categories: record-keeping, analysis, and planning. Information that a probation officer needs may come from various sources or in different formats. GIS provides an integrated environment to support all these three tasks an officer has to perform.

Data set

In this paper, our implementation used a data set provided by the Court of Common Pleas, Probation Department of Cuyahoga County, Ohio. The data set consists of records of demographic, educational, social and economical information of 580 probationers. Table 1 provides profiles of the clients included in the data set. Among these clients, the majority are unemployed single males at young mature age who received education at grade 13 or lower. Using risk and need classifications similar to Baird, Heinz and Bemus (Baird et al., 1979) and National Institute of Corrections (1981), slightly more than half of the 580 clients were classified as high risk to the community and in maximum need of assistance.

Data integration

To implement a GIS for probation records, several different types of data have to be integrated into one commonly accessible database. We built our GIS database by importing TIGER/Line Files for Cuyahoga County, Ohio (released by the Bureau of the Census, 1990). TIGER/Line Files were processed to create two *layers*, including a layer of census tracts and a layer of street network.

Table 1. Profiles of probationers

Probationer Profiles	1st Group		2nd Group		3rd Group	
		(%)		(%)		(%)
Age	<18	0.7	19–35	73.1	>35	26.2
Sex	male	78.8	female	21.2		
Race	white	32.4	black	63.3	others	4.3
Marital status	single	58.1	married	18.8	others*	23.1
Current employment status	full time	22.2	partime	8.5	no job	69.3
Currently receiving benefits	yes	44.7	no	46.9	no info	8.4
Time at current residence	<1 yr	43.3	1–2 yr	10.7	>2 yr	46.0
Highest academic level	< grade 13	86.7	grade 13+	13.3		
Need employment assistance	yes	60.0	no	40.0		
Need academic assistance	yes	36.0	no	64.0		
Need domestic assistance	yes	12.2	no	87.8		
Need substance abuse assistance	yes	46.0	no	54.0		
Need living assistance	yes	11.0	no	89.0		
Prior alcohol/drug treatment	yes	19.1	no	80.9		
Number of prior felony convictions	none	39.0	once	22.6	> once	38.4
Number of times sentenced to prison	none	61.6	once	30.0	> once	8.4
Number of felony offenses while on probation	none	62.4	once	36.4	> once	1.2
Number of felony offenses in last 5 years	none	45.5	once	37.4	> once	17.1
Number of prior juvenile arrests	none	84.1	once	5.2	> once	10.7
Risk class	high	60.3	medium	18.6	low	21.1
Needs classification	high	53.6	medium	26.5	low	19.9

* Others include widowed, divorced and those with no information available on marital status.

Data from Population and Housing Census 1990 were incorporated into the layer of census tracts to form the first part of our GIS database. Using the addresses of client records in probation data, the second part of the GIS database was built to hold the geographic locations of probationers' residences and their associated information. Census data incorporated into our tract layer include a set of carefully selected demographic, socio-economic, and educational variables. These data were incorporated to support data analysis to be described in the next section.

Information about each probation client was taken and coded from the information sheet of Cuyahoga County Community Corrections Intake Form. This information was to support probation management in profiling clients, and to *geo-code* the geographic locations of their residences. The process of geo-coding is commonly referred to as address-matching in GIS. The procedure was to match the clients' street addresses with records of street segments in the layer of street network. Each time a street address was found in a GIS database of street network, a point was established as the reference point for associating all information related to the matched street address. Figure 1 shows the results of geo-coding 580 clients on the 1990 TIGER/Line Files. Squares, circles, and triangles show the locations of probationer residences at high, medium, and low risk classes, respectively.

Once GIS layers are established, probation management can be operated in an interactive environment. Officers can produce maps showing distributions of probationer residences according to a set of criteria selecting subsets of clients. Officers can plan visitation routes using the layer of street network. Moreover, officers can study the composition, profiles, and socio-economic characteristics of their clients.

Automated management of databases

The information stored in the created databases can be retrieved, updated, or modified as in any database management system or spreadsheet programs. In addition, data are given

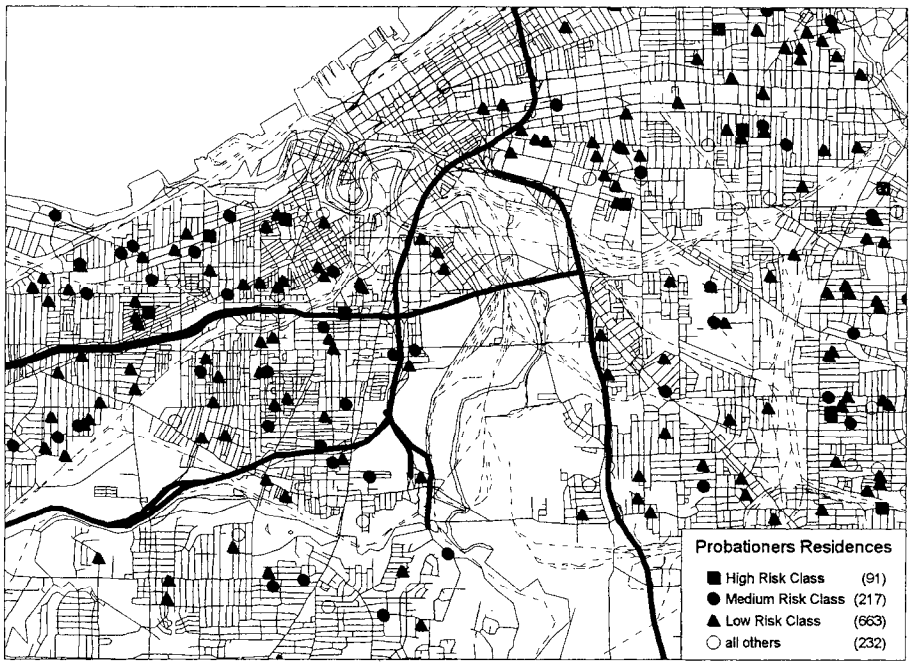

FIGURE 1. *Geo-Coding.* **Probationer residences were geo-coded on the street network database using address matching procedures. Using the street addresses, each probationer's record was matched with the GIS database. Points were established as the geographic locations of probationer residences. They were shown in this map by three symbols for high, medium, and low assessed risk classes.**

geographic references in terms of their locations so that officers can use maps to show their distributions and to examine if there are any geographic patterns.

Dynamic mapping of probationer and other related information

The residences of probationers can be mapped on computer screens or output to papers dynamically by including or excluding one or both GIS layers interactively. The layer of probationer records would support mapping of the locations by offense types, age/sex groups, or by particular socio-economic or educational background. This function enhances the understanding of geographic distribution of probationer residences by allowing direct comparisons between variables in spatial terms. Furthermore, different symbols may be used to represent the variable attribute values for clear representation of the spatial patterns under investigation.

Multiple criteria filtering

The mapping of probationer distributions can be conducted by filtering all probationer locations according to a set of officer-defined criteria. For example, one could choose to display only those locations of a particular type of offense, at a particular risk class or need class, by a particular age/sex/educational background of probationers. In this fashion, the resulting maps reveal various geographic patterns that cannot be obtained by traditional approaches of statistical or numerical analysis of tabulated data.

A subset of the 580 probationers in the data set was extracted and mapped as in Fig. 2.

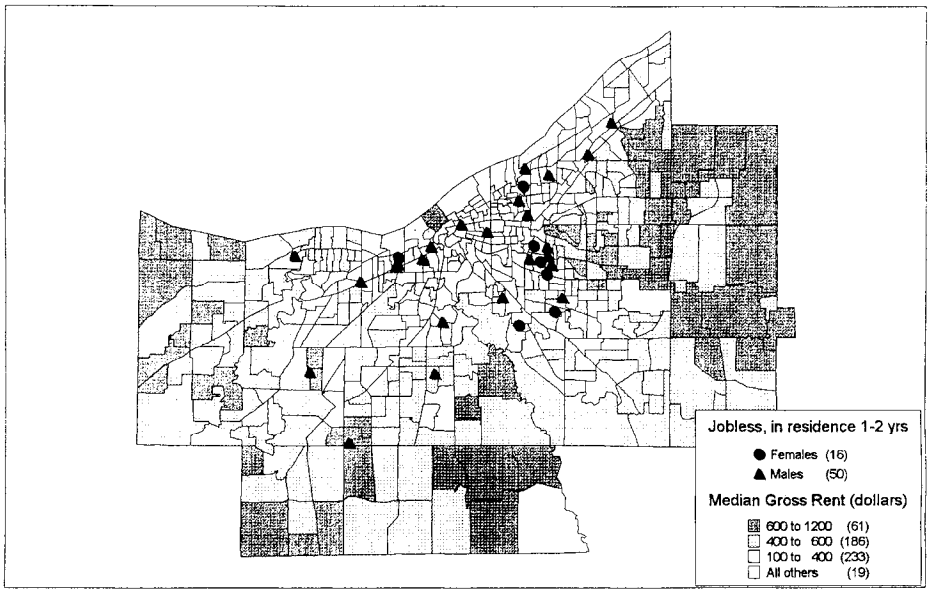

FIGURE 2. ***Multiple Criteria Filtering.*** **Records in GIS Database can be selected for dynamic mapping through a set of officer-defined criteria. In this example, probationer residences were selected such that only those unemployed and those residing between one and two years at current addresses were mapped. Different symbols were used to represent gender differences. The background layer depicts census tracts by median gross rent in three intervals.**

This clearly shows the distribution of the residences of probationers who were unemployed and stayed one to two years at their current addresses by gender. In addition to the mapped distribution, Fig. 2 shows the distribution of median gross rents by census tracts. This map allows probation management to examine the relationship between this particular probation population and its distribution of housing rents.

Quantitative analysis

Our implementation of a GIS for probation management included quantitative analysis to investigate the relationships among the incorporated variables. The analyses were conducted to gain more understanding about the socio-economic characteristics of probationers in the data set. Three themes were examined. First, we looked at the relationship between risk classes and other variables in the database of probationers. Next, we examined the correlation between numbers of probationers in each census tract and the selected demographic, socio-economic, and educational variables. Finally, density surfaces were estimated to give general trends of geographical distribution of probationer residence.

Correlation

Two methods were used to measure the relationships among variables. Between variables whose values were measured at nominal scale, X^2 (Chi-square) statistics were used to test the statistical significance of relationships between variables. Between variables whose values were measured at interval/ratio scale, we used Pearson Product Moment Correlation Coefficient to measure the direction and strength of correlation between variables.

The X^2 test is a very flexible test which is the most appropriate for nominal (frequency)

Table 2. Analysis of probationer profiles with their assess risk classes (X^2 statistics)

Probations' profiles	X^2 versus risk class
Needs classification (high, medium, low)	129.0015**
Number of prior felony convictions	40.3896**
Number of felony offenses in last 5 years	29.2155**
Number of felony offenses while on probation	25.6609**
Number of times sentenced to prison	20.7735**
Needs employment assistance (yes/no)	18.6313**
Presentence recommendation†	12.1313**
Degree of most serious charge	11.8066**
Primary current offense type‡	9.8657**
Prior alcohol/drug treatment (yes, no)	9.2572**
Nees substance abuse assistance (yes, no)	7.8905*
Verified current employment (yes, no)	7.2485*
Race (White, non-White)	7.0569*
Highest academic grade	6.9888*

** Statistically significant at $\alpha = 0.01$ level; * statistically significant at $\alpha = 0.05$ level.

† pre-sentence recommendations may include: regular probation, with intensive supervision, with work release, with home detention, with other programs, shock probation, incarceration, others, no information.

‡ primary current offense types are murder/manslaughter, rape/sexual offenses, robbery, burglary, assault, illegal weapons, theft, drug trafficking, other drug related offenses, forgery/uttering, arson, fraud, others.

data and is nonparametric. It can be used as a test of the *goodness of fit* of an observed set of frequencies produced by a sample investigation to a theoretical frequency distribution. When used as a test of whether there is a difference between two samples of data expressed in frequency form, X^2 statistics test the relationships between attributes in the format of *contingency tables* (see for example Ebdon, 1985, pp. 65–70). In a contingency table, each cell contains an actual frequency count of the number of cases satisfying the characteristics indicated by the column attribute and the row attribute. For each cell, an expected (theoretical) frequency can be estimated by multiplying column total with row total then dividing them with grand total. The X^2 statistics can be computed by:

$$X^2 = \sum \frac{(O - E)^2}{E}, \tag{1}$$

where O and E are the actual and expected frequency counts for each cell.

Table 2 summaries the results of the relationships between the assessed risk classes and other variables about probationers. The X^2 statistics were used to test the relationships because the majority of data were measured at the nominal scale. At this individual level, the results showed that the assigned risk classes were highly related to, in a descending order, the needs classification, prior offenses/convictions, and so on. Not as much but still statistically significant, risk classes are showed with educational background, race, and employment.

For data measured at interval/ratio scales, such as those taken from the 1990 Census of Population and Housing in our implementation, we used the Pearson Product Moment Correlation coefficient. This is a parametric measure of the relationship between two variables (Ebdon, 1985, p. 90):

$$r = \frac{\sum xy/n - \overline{xy}}{S_z S_y} \tag{2}$$

Table 3. Analysis of numbers of probationers by census tracts (Pearson correlation coefficients)

Variable groupings	Variables of probationers' census tracts	Correlation with Nos of probationers
Demographic variables	% Population, Retired	-0.20155**
	% Population, White	-0.37190**
	% Population, Black	0.35419**
	% Population, Native	0.01699
	% Population, Asian	-0.18267*
	% Population, Other	0.09696
Socio-economic variables	% Population on public assistance	0.37124**
	% Vacant homes	0.23578**
	Median income	-0.34885**
	Median house value	-0.29714**
	Median gross rent	-0.24796
Educational variables	% Population with no high school	0.13902*
	% Population with some high school	0.36056**
	% Population of high school graduates	0.02097
	% Population of some college	-0.10397
	% Population with associate degrees	-0.11868
	% Population with bachelor degrees	-0.34239*

** Statistically significant at $\alpha = 0.05$ level; * statistically significant at $\alpha = 0.01$ level.

where x and y are variables being examined with means of $\bar{x}$ and $\bar{y}$ and sample standard deviations of S_x and S_y. The resulting coefficients would have a range from -1 (strongest negative relationship) to $+1$ (strongest positive correlation).

At a more aggregated level, we looked at how numbers of probationer residences were related to a set of demographic, socio-economic, and educational variables. These results are listed in Table 3. For census tracts in which there was a smaller minority population, higher median income, less vacant homes, and more educated population, there seemed to be fewer probationer residences. As a general trend, this pattern agreed with studies and literature in probation.

Density estimation

In GIS, a very efficient method for producing generalized trends of spatial data is to interpolate point data into surfaces. Through three dimensional graphic representations, the spatial trends embedded in the data can be detected easily for further interpretation. For frequency data, such as the residence locations of probation clients, it is particularly appropriate to use the method of estimating density surfaces. Their geographic distribution can be visualized through plotting the estimated surfaces into three dimensional block diagrams such as those in Figs 3 (a–c).

The procedures for estimating density surfaces are simple. A very fine grid is first laid over the study region, dividing the entire area into a grid of the size of r rows and c columns. Density surfaces are then estimated by accumulating the frequencies at all cells. Frequencies are added by density cones placed at the locations of all data points. A density cone can be thought of as a bell-shaped frequency distribution with the highest density at the center and decreasing densities at locations moving away from the center. Using each data point as the center, a density cone adds frequencies to cells at and surrounding each data point. Density surfaces are the results of accumulating all frequencies added by those cones. Detailed discussion of procedures for density estimation can be seen in Brunsdon (1991)—a study using density estimation to generate probability surfaces for locations of household burglaries.

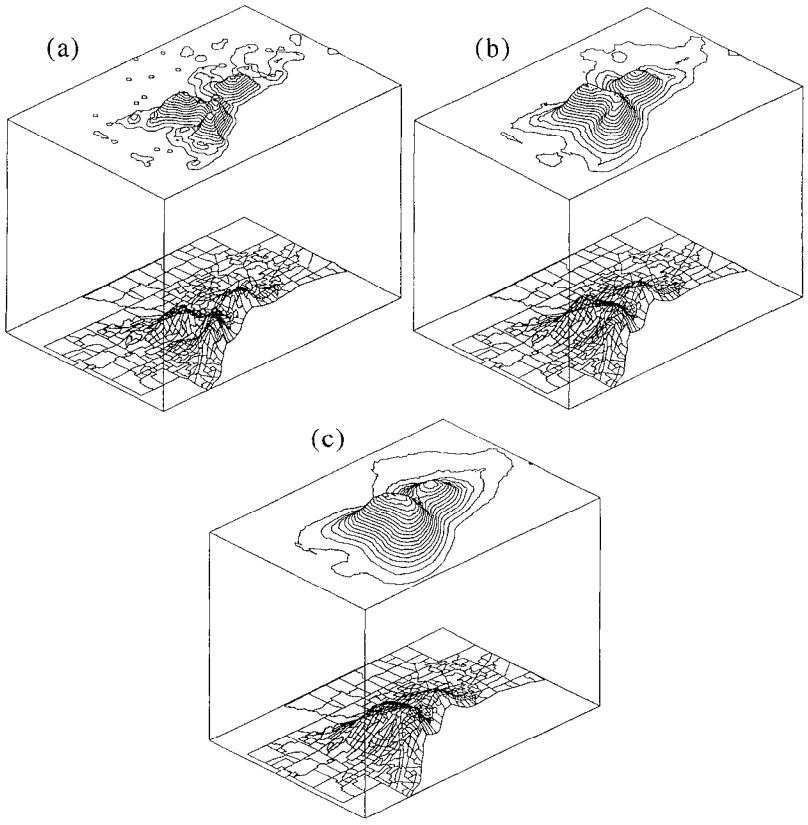

FIGURE 3. (a) Density Surface with 15×15 Density Cone. (b) Density Surface with 30×30 Density Cone. (c) Density Surface with 50×50 Density Cone.

The size of grid cells is generally referred to as the resolution of the grid and is decided by researchers based on their estimation of the details needed for their study. The size of the density cones can be decided somewhat arbitrarily, depending on how generalized researchers want the resulting surfaces to be. Figs 3(a–c) show the results of density estimation using the locations of probation clients. Each of the three-dimensional surfaces was depicted by contours starting at 100 (frequencies) with 200 as contour interval. Below each 3D block diagram, boundaries of the census tracts in Cuyahoga County were also raised in vertical heights proportionally to give a more realistic view of the estimated surfaces.

Fig. 3a was generated by using a density cone of 15×15 cells while Figs 3(b,c) were generated using cones of 30×30 and 50×50, respectively. Clearly the smaller density cones generated surfaces that were more rugged than those generated by larger cones. In Fig. 3a, three peaks close to downtown Cleveland characterized the distributions of probation residences. When density cones were increased to 30×30 as shown in Fig. 3b, two of the three peaks seemed to link up, forming a ridge line. With 50×50 density cones, the estimated density surface gave two high density areas generally in the inner areas of the great Cleveland Metropolitan region.

CONCLUDING REMARKS

Given that probation programs need efficient tools to cope with increasing caseloads and relatively low levels of funding, we suggest using geographic information systems as an integrated environment to assist probation officers in managing their program. Our implementation demonstrated the feasibility of this concept.

We argue that GIS provides an integrated, interactive environment for probation officers to manage their clients. Information on probation clients can be entered, updated, or modified. Locations of probationer clients can be mapped with any incorporated demographic, socio-economic, or educational variables to give probation officers sufficient background information and in-depth understanding of the profiles of their clients. Dynamic mapping and multiple criteria filtering offer an interactive setting for efficient management of probation data. Finally, density surfaces allow generalized trends to be constructed for further spatial analysis of respective probation programs.

As a spatial decision support system, GIS possesses a wide variety of functions for analyzing and displaying geographic information. For probation management, the potential of using GIS to increase efficiency and productivity is great, as demonstrated in our implementation.

ACKNOWLEDGEMENTS–The author would like to extend our appreciation to the Urban Universities Program for funding, to the Cuyahoga County Court of Common Pleas for providing data, and to Alec Boros for his assistance in data coding and preparation for this project.

REFERENCES

Baird, S., Heinz, R. & Bemus, B. (1979). *The Wisconsin Case Classification/Staff Development Probation Projects*. Washington, DC: United States Government Printing Office.

Banks, J., Porter, A., Rardin, P., Silver, T. & Unger, V. (1977). *Evaluation of Intensive Special Probation Projects*. Washington, DC: United States Government Printing Office.

Bemus, B. & Baird, S. C. (1988). *Workload Measures in Probation and Parole*. Madison, WI: National Council on Crime and Delinquency.

Brunsdon, C. (1991). Estimating probability surfaces in GIS: an adaptive technique. In J. Harts, H. Ottens, & H. Scholten (Eds), *Proceedings of the Second European Conference on Geographical Information Systems* (pp. 155–64). Utrecht, The Netherlands: EGIS Foundation.

Clear, T. R. & Braga, A. A. (1995). Community corrections. In J. Q. Wilson & J. Petersilia (Eds), *Crime* (pp. 421–444). San Francisco, CA: ICS Press.

Cunniff, M. & Shilton, M. (1991). *Variations on Felony Probation: Persons under Supervision in 32 Urban and Suburban Counties*. Washington, DC: United States Department of Justice.

Dillingham, S. (1990). *National Corrections Reporting Program, 1985*. Washington, DC: National Institute of Justice.

Ebdon, D. (1985). *Statistics in Geography*. Oxford, UK: Basil Blackwell Ltd.

Langan, P. (1994). Between prison and probation: intermediate sanction, *Science, 264*, 791–793.

National Institute of Corrections (1981). *Model Probation and Parole Management Project Handbook*, Washington, DC: National Institute of Corrections.