Electronic Mapping Research and Development

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• A RECENT research and development contract between the University of Washington and the City of Spokane Urban Renewal Department is the basis for an entirely new type of research in both computer applications and urban analysis. This project involves the electronic positioning of selected information from a large universe of data stored on magnetic tape. The actual mapping of the information can be effected either through use of conventional electronic printout equipment (such as the IBM Model 717) or photographed from an image displayed on a cathode-ray tube. In either method, the data shown must be interpreted through an overlay grid or an outline map of some type that enables the viewer to interpret the positioned data in terms of a frame of reference. The superimposition of the reference screen or base map is generally effected in the photographic stage by the use of an overlay map, drawn on clear acetate, showing some features of the city. The base map or grid can also be developed by using an electronic scanner to record the base-map outline and then displaying the base map simultaneously with other desired information on the cathode-ray tube.

The construction of maps through electronic techniques is by no means new. The U.S. Weather Bureau pioneered what is known as a "printout" system for representing certain weather information collected from field stations covering a broad expanse of the earth's surface. However, most of the development of electronic mapping to date has been achieved with machines that actually plot lines. These machines generally make use of an inking head that may be directed to any spot on a plane surface by using either punched cards or taped information. The lines are constructed as vectors, and curved images are possible only by the use of a series of very short straight-line elements. The disadvantage of the ink plotter is that it is extremely slow when compared to either a printout or a cathode-ray tube display; nevertheless, it has great utility in many fields. One example of how it is being used is the contruction of "traffic trees," a series of desire lines of flow tracing the pattern of movement from any designated traffic-enumeration zone to all other zones of the system. A desire line is a straight line drawn from the point where the traveler begins his trip to his destination. Not only can these straight lines be generated to represent desires-of-flow direction, but a width band of parallel lines may also be made to represent the volume of traffic flow. This type of plotter can also stamp numbers any place on the plane surface, indicating quantities such as traffic volumes or ground elevations.

The cathode-ray tube may also be used to show desire lines of travel by the generation of the vector on the surface of the tube representing the origin and destination of the trip. In the Chicago Area Transportation Study this technology was used to record the traces of all daily trips made in the Chicago area on a typical day. A total of 2,900 one-quarter-square-mile grid units were used to define the points of origin and destination of the desire trips. Each trip showed as a lighted trace on the cathode-ray tube, and some degree of total trip volume could be comprehended from a photographic recording of the total amount of light displayed by the 400,000 trips simulated on the face of the tube. This particular job, which took 3½ hours of machine time, represented information that could never have been done by hand and that also showed many characteristics of travel never before viewed. For example, when all of the trips between 8:00 and 9:00 PM were simulated and displayed photographically, the viewer could get a fairly good idea of the trade area from which the patrons came to each of the local shopping centers. These procedures were developed in 1959.

PROJECT

The University of Washington project on electronic mapping is unique for several reasons. First, it deals with a universe of several million pieces of information representing many different types of measurements used in urban analysis. Second, it is developing a technology for mapping much of this information in symbolic form, representing an event either by a symbol on a map or by symbols indicating some scale of intensity for the events recorded. Third, by the use of bar charts and distribution curves, it shows alongside the map statistical information that enables the viewer to see at one glance not only that portion of the distribution curve he is looking at, but also where that portion of the distribution curve or data array is located in space. (These have been termed statistagraphs). Although the collection and storage of data by electronic means for urban analysis has been used for a few years, this is the first time that the automation process includes the mapping of data and the use of the new features just mentioned in the graphing of the data.

An interesting sidelight of the project is the development of a program that will translate a street address into a position on the map. In this way it is possible to show quickly any information that is recorded by an address, such as particular type of industry, a police call, or a case of illness representing a particular disease. For example, one could trace the spatial aspects of an epidemic through periodic runs of cards on which the home addresses of the diseased people were punched. The importance of this address-translation program, however, lies in the fact that it can immediately print out information from cards that have already been collected for other purposes by public agencies and private firms.

Because the client agency for the particular research and development under discussion is an urban-renewal department of government, the mapping and graphing contemplated by this project relates mainly to information significant to an urban-renewal program. In fact the mapping development is part of a larger program, the Community Renewal Program (CRP), that the City of Spokane is currently undertaking. This program, which receives two-thirds of its financial support from the Federal government, is designed to study the long-range total urban-renewal needs of a city and to set up criteria for the delimitation and scheduling of specific urban-renewal projects. The data collection for the Spokane CRP, under the general supervision of the University personnel concerned with the electronic mapping project, has involved the development of over 70,000 punched cards representing information on every piece of property in the city. This information includes the type of use of the property; the ground area of the lot; assessed valuation; floor area, age, and condition of the building; and other pieces of information relevant to urban-renewal study. Additional information punched on 25,000 other cards is fed into the storage system from census data available from the Federal government and data collected by the State of Washington through the Employment Security Department and the Tax Commission. After the punched data are recorded on cards; the information is transferred to magnetic tape from which various summaries and computations can be made in connection with the mapping process.

At the time of this writing the data-collection phase has been concluded and over 1,000 graphs and maps have been produced. An estimate indicates that for as little as between $0.03 and $0.05 apiece this method can produce maps or graphs that would cost up to $100 to produce by hand, and the machine output produces this information at the rate of between 20 and 30 maps per minute. An interesting aspect of the technology is that hundreds of maps, if not thousands, can be produced as a basis on which to develop a screening for observing conditions that may or may not be significant to examine in greater depth. In contrast, with hand-constructed maps, so much money is committed to the production of the map that certain conclusions must be drawn before it is made.

APPLICATIONS

City Planning

There is little doubt but that the city planning field is on the verge of a great revolution in methods of data handling. Although it is now almost three-quarters of a century since Holeruth first introduced his dollar-sized punched card into data collection technology, the advances of the last half-dozen years have been staggering in regard to implications for the future. Although the authors are well aware that data collection and manipulation is not a substitute for policy and programing on the planning front, nevertheless, the planning professional may soon become relieved of the tediously slow, subprofessional tasks that have absorbed the energies of the profession for so long. The land-use map, the census analysis, and the vast record keeping associated with planning administration may become the work province of subprofessionals at least as far as all the routine phases are concerned.

The beginnings of the new technology, as far as city planning is concerned, have been the rudimentary collection of data on punched cards and the application of simple accounting procedures to this store of data. As a matter of fact, some agencies kept records in some detail on punched cards for many years. The real breakthrough, however, comes in the realm of data manipulation, recall, and now plotting and mapping by electronic means. Although the development of programs and the pioneering of a new technology requires a specialist approach, there is no doubt that the product can be institutionalized to the point where almost every planning operation having at least one competent professional can automate large segments of the local planning operation. Nor will the lack of a close-by sophisticated computer inhibit automation and the newly emerging techniques by those whose fortune is not to be located near these centers. There now exists ample opportunity for both cards and tapes to be sent to computer service centers. There is no doubt that service centers will not only grow but become more specialized as time goes on and that a library of programs will become developed for use by city planners and urban researchers.

The question may be raised whether these sophisticated techniques are not beyond local authority to make a large initial investment. There is no doubt that there are some birth pangs in breaking into a new technology on any level. Planners have to readjust their thinking, and there is a backlog of information to be put on punch cards. Particularly, planners in small cities may wonder as to the practibility of data automation for their cities as well as its cost. However, apart from developing a system that will be refined to the extent of using individual property cards, the planner for a city of 40,000 or 50,000 people can put all of its census enumeration district information on cards and construct perhaps 1,000 charts and graphs for as little as one month's salary for the typical draftsman. The payoff really comes over a period of time, as data are gradually added to a growing reservoir or as data are updated. Conceive of the ability to call for a time series of data covering ten or fifteen years of events of a particular category by merely placing a call to a computer service center where tapes of the particular city are kept and where the produce can be returned within 24 hours.

A look into the future, judging by the present demonstrated results in electronic mapping and plotting, indicates the following as just a few of the possibilities:

1. Studies of the Urban Structure for Long-Range Planning.
    a. The development of residential density-distance curves for various points in time and their automatic extrapolation to a planning target date. (These plot density as the ordinate and usually time-distance as the abscissa.)
    b. The development of models showing variation in rents with distance from the central business district, by means of which an automatic screening can be made of those areas of the city that are significantly underdeveloped in terms of either use or investment potential (as measured by rents which deviate substantially from the model).
    c. The allocation of population to various subareas of the city, down to a neighborhood level by automatic means and based on area-wide historical trends, subarea growth models and other parameters of data amenable to machine processing.
    d. The delineation of nonresidential functional use areas in which different activities cluster are determined by the automatic mapping of establishments of different types.

2. Studies Relative to Short-Range Planning.

    a. The automation of building permit records to show at a glance by electronic mapping and graphing a running account of land consumption, investment in building, housing demand, and locations of high developmental demand.
    b. Floor-area ratio accounting to show at a glance and keep a running tab on the relationship of building to ground area in terms of the preservation of site amenity (also population density studies).
    c. The automation of all growth indexes and graphs of socio-economic data normally used as part of the economic base study.
    d. Automation of the U.S. Census data, as they become available, for rapid plotting and graphing.

3. The Automation of Planning Administration Records.

    a. The recording of all zoning adjustment cases for instantaneous recall by both written description of the case and map location by which to compare the case at hand with others of similar nature.
    b. The recall and plotting of all known functional or legal nonconforming uses related to zoning adjustment applications.
    c. The storage of information on tape for printout of all official records, notices, and filing purposes regarding zoning adjustment cases.
    d. The immediate plotting of field land use data collected by "porta-punch" method of information relative to any particular zoning study or adjustment case.

There is almost no limit to possibilities of integrating automation in all phases of municipal planning operations. Once information has been recorded on cards there are many operations that can be handled without the use of sophisticated computers. For example, sorters, accounting machines, and printers are to be found in every metropolitan center and in many of the smaller cities as well. There are all levels of sophistication of programing, and once instructions have been written for some of the less complex machines, significant use can be made of them in terms of developing both graphs and maps. A final example in the city planning field is the use of the computer to write reports, including both text and illustrations. It is possible now to assemble information on tape and to program in its format as to margins, spacing on the page, right marginal adjustment, footnotes, and other features that will materially expedite the prepartion of reports and preclude the need for recopying most of the information from draft to draft.

In summary, regardless of whether planning follows a conceptual framework based on market processes or is based on doctrinaire schemes, it must evolve from a detailed knowledge of the present order and a knowledge of what is involved in changing the existing order. To this end, the new electronic tool can be of material benefit in giving the professional planner a true picture and far more extensive picture than ever was possible before.

Transportation Planning and Traffic Engineering

Mention has already been made of the development of the cathode-ray tube display by the Chicago Area Transportation Study in showing desire lines of travel between one traffic enumeration zone and another. In addition to showing desire lines of travel, the Cartographatron developed by CATS has been used to show such data as the origin of persons walking to suburban or elevated subway trains, the origin of persons riding to these same transportation modes, the origins of shopping trips to the CBD, the origins of work trips to the CBD, internal persons-trips of varying length, the origins of trips to shopping centers, and other data that aid in understanding transportation movements in an urban area. All of the displays shown in the Chicago study have been assembled from sample data, either collected by home interview method, post card method, or cordon counts. In all cases, the origins and destinations and trips were first coded to zone location and then tallied to give total values for that particular zone.

A somewhat different but unique application of electronic plotters is being made currently by the Penn-Jersey Transportation Study. In this case the EAI plotter, with a punch card input is being used both to plot traffic assignment trees and to register data according to coordinate locations by the registration of a positioned dot on the map. An example of the latter use is a map showing the first work trip destination of all trips. In this case, tallies are arrived at for each destination zone and represented according to graduations of scale by different colored dots. For example, destinations of certain ranges of numbers show as yellow, and the next higher stratification as green, the next as blue, and finally the heaviest concentration as black. Another example is a display of population density by a similar color variation. The results in both these examples can be read much like contour maps. Use of the EAI electronic plotter is very slow when compared with either the print-out positioning of dots using such equipment as the IBM 717, or cathode-ray tube displays such as the IBM CRT 740 or the General Dynamics SC-4020. However, if the EAI plotter is part of an equipment pool either rented or owned by the particular agency, then the fact that it takes five minutes to construct a map which otherwise would be constructed in a few seconds by other equipment may be immaterial. The slower plotter may be standing idle otherwise, and it can do things the other display instruments cannot do.

An interesting graphic display has been produced at the Penn-Jersey study by stratifying data and reproducing each range as a color scale on a chronoflex transparency. In this way, a great variation in shades or colors can be obtained, and the resulting maps can be superimposed on each other for pictorial display by the use of an opaque projector.

University of Washington studies in electronic mapping and graphing will produce transportation planning data of a considerably different nature than that previously discussed, partially because the data relate to a city and do not involve sampling. By virtue of having a street address translation program, resulting from the complete coverage of every establishment in the city in punch card coding, it will be possible to print out on a map, automatically, the home locations of workers at a plant if their addresses are coded. Most industries of any size already have the addresses of their employees recorded on punched cards. In other instances, the addresses of employees are available on cards from State employment security records. The automatic plotting of the home locations of the workers of a particular plant opens the door to a new front in the analysis of the aggregation of worker's residences with respect to any particular plant, or group of plants. Evidence is already at hand, as pointed out by Nathan Cherniak at the Highway Research Board Annual meeting of 1960, that the aggregation of employee's residences with respect to distance from the work place can be reasonably described by a model. For example, in his studies of the locations of workers employed at the New York International Airport, Chernaik found that the percentages of the total number of workers residences in the range of time-distance bands diminished with distance from the work location according to a simple exponential function. One may query here whether the time has not come for a greater use to be made of destination type surveys. If the kind of information being assembled for the city of Spokane in the University of Washington studies were readily available in most cities, as it is evident will happen within the next decade or so, then the door is open to make extensive destination type surveys at a minimum cost to cover at least the work trip portion of the urban transportation universe. This kind of a survey certainly may bring out a different picture of traffic movements than obtained by the customary Lynch origin and destination survey, or on the other hand if found to corroborate the customary O-D survey it might be used as a substitute. There is an inherent weakness, in any event, in the expansion of a small sample obtained by a home interview survey of all trips, and then taking 11 or 12 percent of the trips as representative of the peak-hour travel, as compared to a specific work-trip survey of relative complete coverage. It might be far cheaper and better to get the peak-hour travel directly and use interview techniques to gain more knowledge of recreation travel or travel for other purposes than work or recreation in arriving at a more complete picture of total urban transportation demands.

The kind of information being collected in the Spokane study will be of great value when motor vehicle license information is stored on magnetic tape. By the use of such storage and the collection of license plate data at either a cordon line or a particular location it will be possible to obtain a vast amount of information on origin and destination regarding urban trip generators. For example, license plates could be photographed by motion picture cameras at the access points to shopping centers or at various other cordons, quickly punched, and transferred to tape for matching with the master tape linking the motor vehicle license number with the address of the owner. From this point it would be an easy matter to map the home locations of the drivers represented in the count.

The street address translation program also opens the door for the immediate rendering of accident data, once these data are represented on a punched card. This would facilitate the production of accident record maps according to hour of the day, time of the year, weather conditions, and a number of other possible segregations of the data. The printout mapping technique being developed in the Washington project will also permit the rapid stamping of traffic counts at locations on a map representing the traffic counting stations.

The frequency distribution and graphing programs are particularly adaptable to selecting the 30th highest hour of traffic flow or other flow levels on which to base design or program improvements. Coupled with the recording of traffic counts on punched tape, there are any number of possibilities to automate the rapid graphic recording of most data collected by traffic engineering departments.

EMERGING SCOPE

Only a few applications of electronic mapping graphing have been given in this paper. The real importance to emerge from the development of this tool will occur as cities automate their systems of collecting, storing, and retrieving data concerning urban activities, (land values, land use, age, and condition of buildings, and all the other things referred to in preceding discussions). The research currently going on at the University of Washington is primarily designed to evolve systems not only for the storage and retrieval of data, but for its almost immediate use in graphical form. This research will continue through 1962, at least, under the sponsorship of several agencies including the National Science Foundation. Results will be reported as they become documented.

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Appendix

SAMPLE MAP AND GRAPHS

Three samples of early products of the electronic plotting are presented here. They are ozalid prints from photographic transparencies of the machine output. The originals can now be produced in just a few seconds, including headings and titles, and at a cost less than that of the vellum or high contrast opaque paper on which they are produced.

Figure 1 shows computed information from a deck of census tract cards. The program will print out either the basic information or derivative information computed from it, according to instructions, and place the results in the appropriate location. Although the space modules of this illustration are census tracts, they could also be enumeration districts, blocks, neighborhoods, or uniform divisions relating to a grid, depending on the way the basic data are punched. The computational results can also be shown in symbolic form, such as the dots, minuses, and pluses of Figure 3. Symbols can be programed to fill up the entire space unit, or any portion of it.

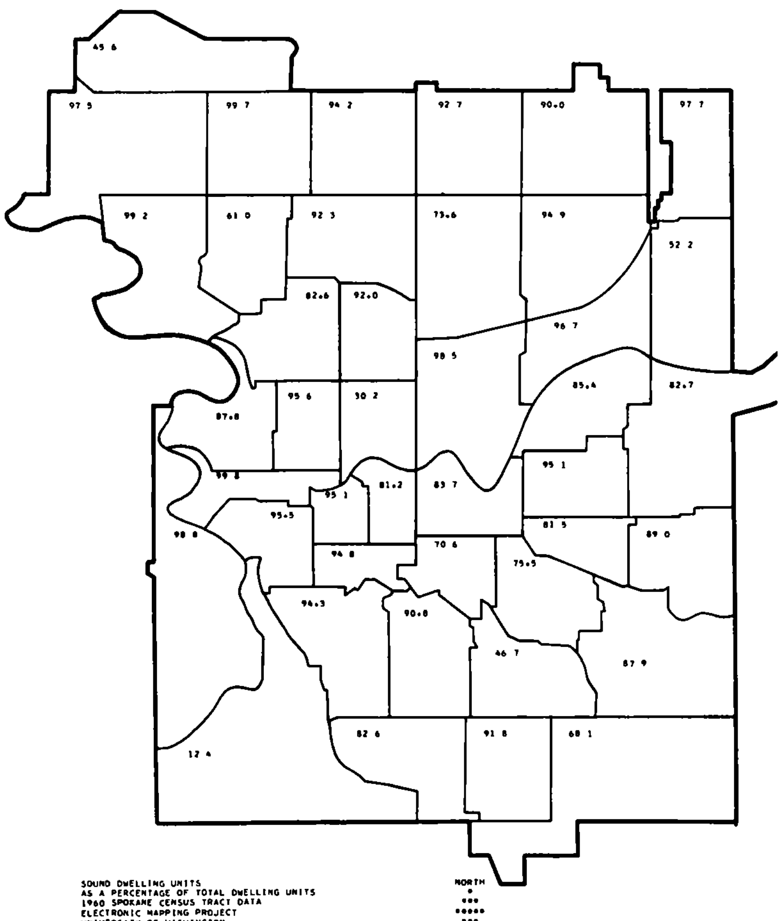

Figure 1.

Figure 2 shows a bar chart on which each census tract is shown in the array in its appropriate place. If more than 50 or 60 basic units are shown (i.e., more than a full page), they can be automatically grouped so as to form a normal distribution curve. These kinds of arrays permit one to come to tentative conclusions as to limits of normalcy. For instance, one can see at a glance just how deviant the extremes are from the normal range; say, all but the first four and last four tracts in the array. The array or distribution curve is especially valid in examining block data, where there is a large universe (say, five or ten thousand blocks) and where a Poisson-type distribution is likely to occur.

Figure 3 shows the same kind of information as Figure 2, except that the first and last quartiles were programed to print in different symbols. Actually, the breaks in the slope of the bar chart curve do not occur at the quartile points, and a plotting of the extreme octiles or deciles would have been more significant. It is expected that programs will be developed in this research to find the extreme ranges automatically. Most important, however, is that when this kind of a plot is shown alongside a map whereon the same symbols indicate the spatial location of the extremes of the array, the viewer sees at a glance both the statistical and locational significance of the data. (This combination of information in one picture is termed a "statistograph.")

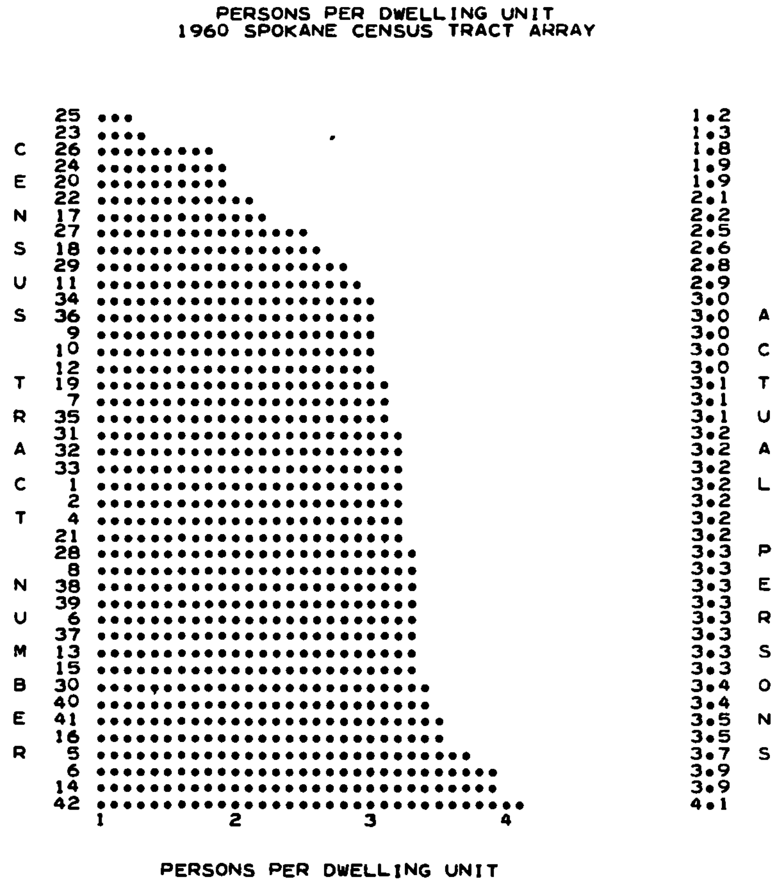

Figure 2.

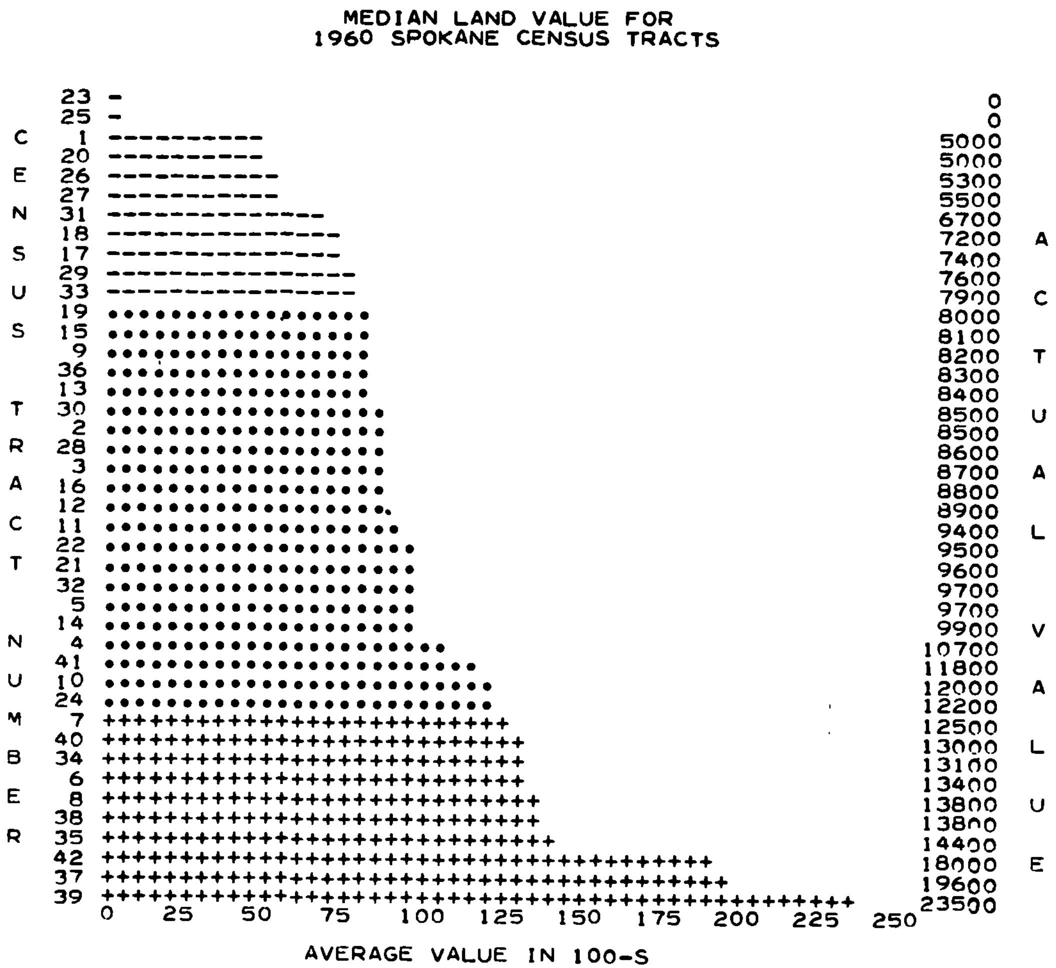
MEDIAN LAND VALUE FOR
1960 SPOKANE CENSUS TRACTS
CENSUS TRACT NUMBER
ACTUAL VALUE
23 0
25 0
1 5000
20 5000
26 5300
27 5500
31 6700
18 7200
17 7400
29 7600
33 7900
19 8000
15 8100
9 8200
36 8300
13 8400
30 8500
2 8500
28 8600
3 8700
16 8800
12 8900
11 9400
22 9500
21 9600
32 9700
5 9700
14 9900
4 10700
41 11800
10 12000
24 12200
7 12500
40 13000
34 13100
6 13400
8 13800
38 13800
35 14400
42 18000
37 19600
39 23500
0 25 50 75 100 125 150 175 200 225 250
AVERAGE VALUE IN 100-S

Figure 3.