The Application of Computer Graphics to Patient Origin Study Techniques

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IN RECENT YEARS emphasis on community planning for hospitals and related health facilities and services has increased throughout the United States. Stimulated by concern for rising hospital costs, increasing utilization, and the expansion of a complex urbanized society, health leaders have urged that areawide planning become the rational basis upon which our health service system grows and develops (*1, 2*).

Changes in population, whether in relation to natural increase or migration, and shifting hospital service patterns make imperative the development of tools which can monitor and report such changes clearly and promptly. Many of the major community studies on hospital planning in the United States in the last decade have been reported 2 or 3 years after the data have been gathered. In such instances the material may be offered for community decision at a time when it is already too late for effective action. The concern of our hospital utilization research project is with the development and application of improved techniques for areawide planning. This paper deals with the development of one new hospital planning technique which may be helpful to institutions and communities as they seek to understand and cope with the aspects of health service patterns in their local areas. Our examples are based on approximately 80,000 hospital admissions in 1962 to 8 hospitals in 127 census tracts in Santa Clara County, Calif., representing approximately three-fourths of a million population.

One of the first concerns in health-facility planning is analyzing the geographic area relating to the hospital-patient service relationship. Many community studies have termed their geographic analyses "patient origin" or "service area" patterns. These patterns have been studied intensively in rural settings by Poland and Lembcke (*3*) and Roth and associates (*4*). Such analyses are of particular importance in metropolitan areas where a multiplicity of hospitals and related health facilities serve people in overlapping patterns. In such situations it is helpful, in analyzing and understanding the patterns, to display them by mapping since it is difficult to comprehend the spatial relationship among geographic areas whether they be ZIP-code zones or census tracts. A person may quickly relate landmarks and community features with which he is familiar to the density pattern of residential areas, the downtown area, major shopping centers, transportation networks, and industrial concentrations, as well as to remaining open land which may be intensively developed in the future (*5*). All have a bearing on intelligent, comprehensive planning of health facilities.

A mapping technique has been developed in the field of urban planning using a general computer program of printing numbers or symbols within a stated geographic area (*6*). Instruc-

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tions are fed to a computer requesting a printout at specified coordinates which have been described previously to the machine. The computer is thus able to produce numbers which fall in appropriately designated places; then outlines of the boundary areas are superimposed to form a map.

In hospital planning, one of the first considerations for a community is to study the areas where patients reside and which hospitals they use for care. At the same time it is also necessary to review the other side of the coin—the "service area" or "draw" of each hospital so that plans may be made for coordinated services with other institutions serving approximately the same basic population or segments thereof (*7*, *8*).

In a sense this concern for geographic analysis is partly paralleled by the development of a birth and death registration system in our country. Both the place of occurrence and the place of residence relating to these events are tabulated. Hospital planning has a need for this same type of information, but only the occurrence data are generally available.

In the past, hospital studies have shown differing rates of hospital use in adjacent portions of States or regions (*9–12*). The traditional statement on "patient days per 1,000 population" does not distinguish between patient days in the hospitals of an area used by its permanent residents and patient days used by other population groups migrating for such service. For reasons of economy, most community patient-origin studies have been of short duration or small-sample size, making extended generalization from their findings difficult (*3*, *13–16*). Another aspect of the problem is that only a few studies of comprehensive health insurance plans have been able to use a known base population (*17–19*).

If all hospital admissions can be related to the patients' places of residence, it becomes possible to determine incidence rates or episodes of hospitalization for that geographic area if the base population is known. Such information gathered at the time of a U.S. census provides maximum accuracy and economy. At the same time, the hospitalization experience may be correlated with the social and economic characteristics of the population, permitting periodic studies of demographic factors that influence the volume and type of hospital services used on a small-area basis (*20*).

Such correlating analyses have been done on a statewide basis for the nation by Rosenthal (*21*). Since medical trade areas for most services are generally much smaller than even the smallest States, small-area analysis assists in the separation of divergent patterns of hospital use, first at the regional level and then at the local level. One such study has recently been completed by Cardwell and associates for the Chicago Metropolitan area (*22*).

In order to have definitive studies at the local level, prompt, accurate data on episodes of hospitalization are necessary. Rather than relying on household sampling, which is expensive, slow, and inherently less accurate, information is best acquired from the providers of service with direct access to definitive hospital reports (*23–26*). The idea of obtaining such episodal data is not new or restricted to general hospitals. The pioneer work by Faris and Dunham (*27*) and more recent work by Bodian and associates (*28*) in the field of mental health are other examples which relate demographic characteristics to incidence rates based on information supplied by the providers of service.

The foregoing considerations have led the hospital utilization research project to adapt and utilize two computer package programs to develop this phase of hospital planning. A package program in this instance denotes that all sequential sorting and positioning of data are done internally by the computer and are dependent on a definite set of instructions. In one of the computer programs adapted for the IBM 709, 7090, and 1401 series, data are read directly from the punchcards. The instruction and data cards are fed simultaneously to the computer.

The computer-card array or sequential display of the number of admissions from a given geographic area is shown in bar graphs. The graphs, printed in dots, represent a distribution in actual value or percent of admissions by geographic areas (for example, census tracts) for an individual hospital or group of hospitals. In this way an administrator or

Figure 1. Array of total admissions to general hospitals in Santa Clara County, Calif., by census tract, 1962

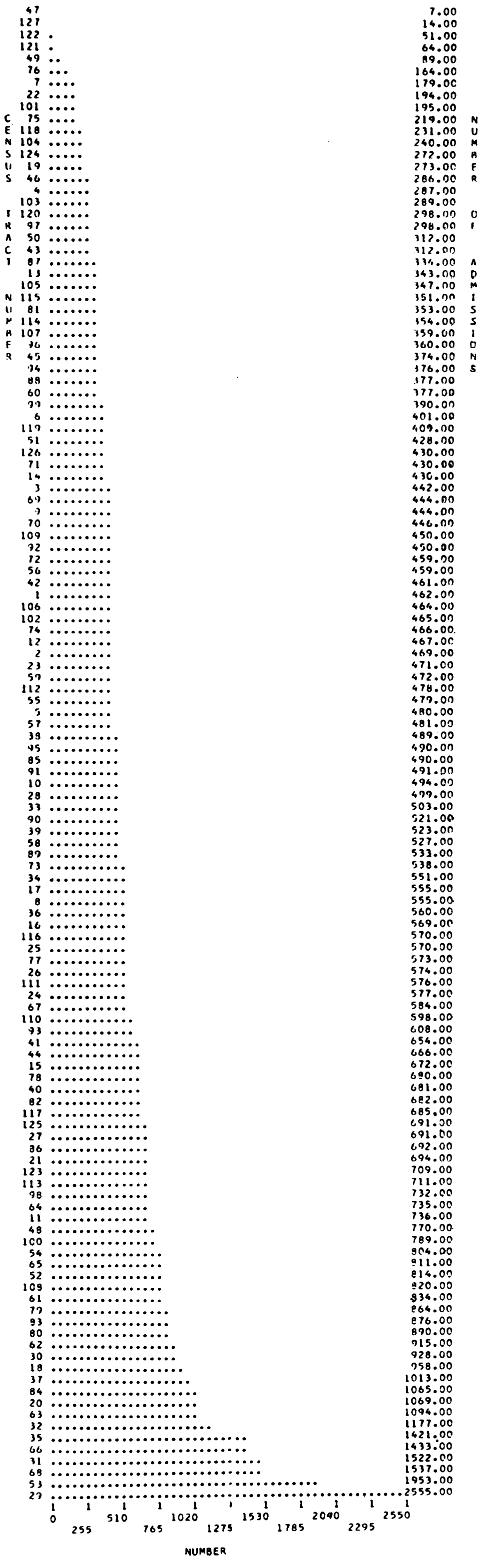


Figure 2. Computer map showing total admissions to hospital X and total admissions to all hospitals in Santa Clara County, Calif., by census tract, 1962

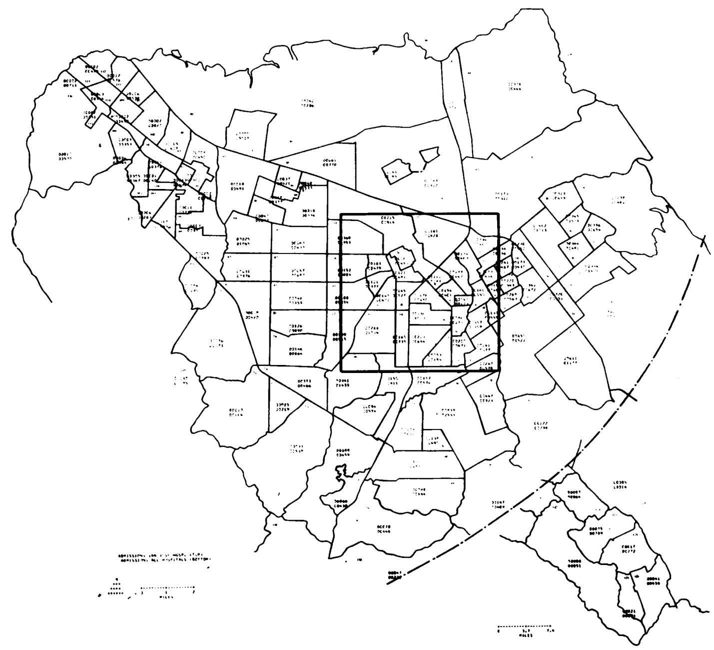
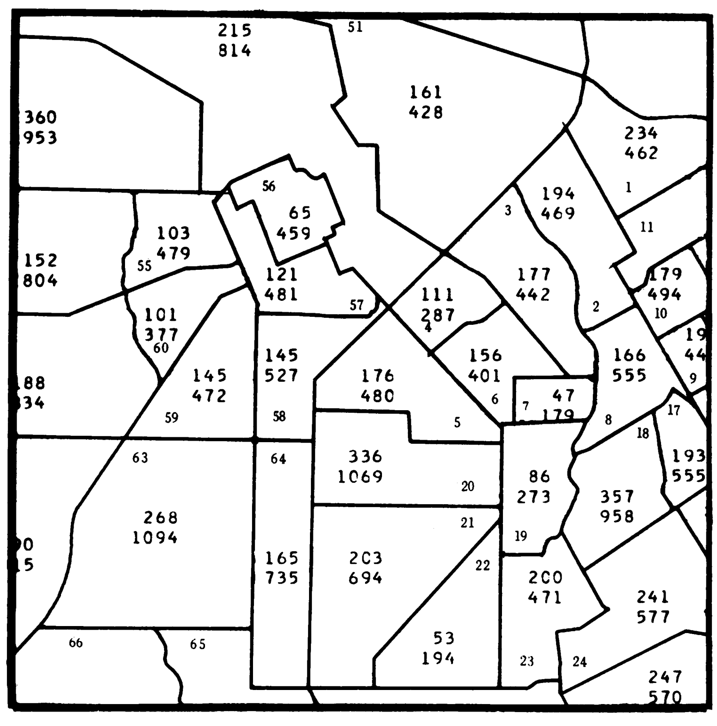
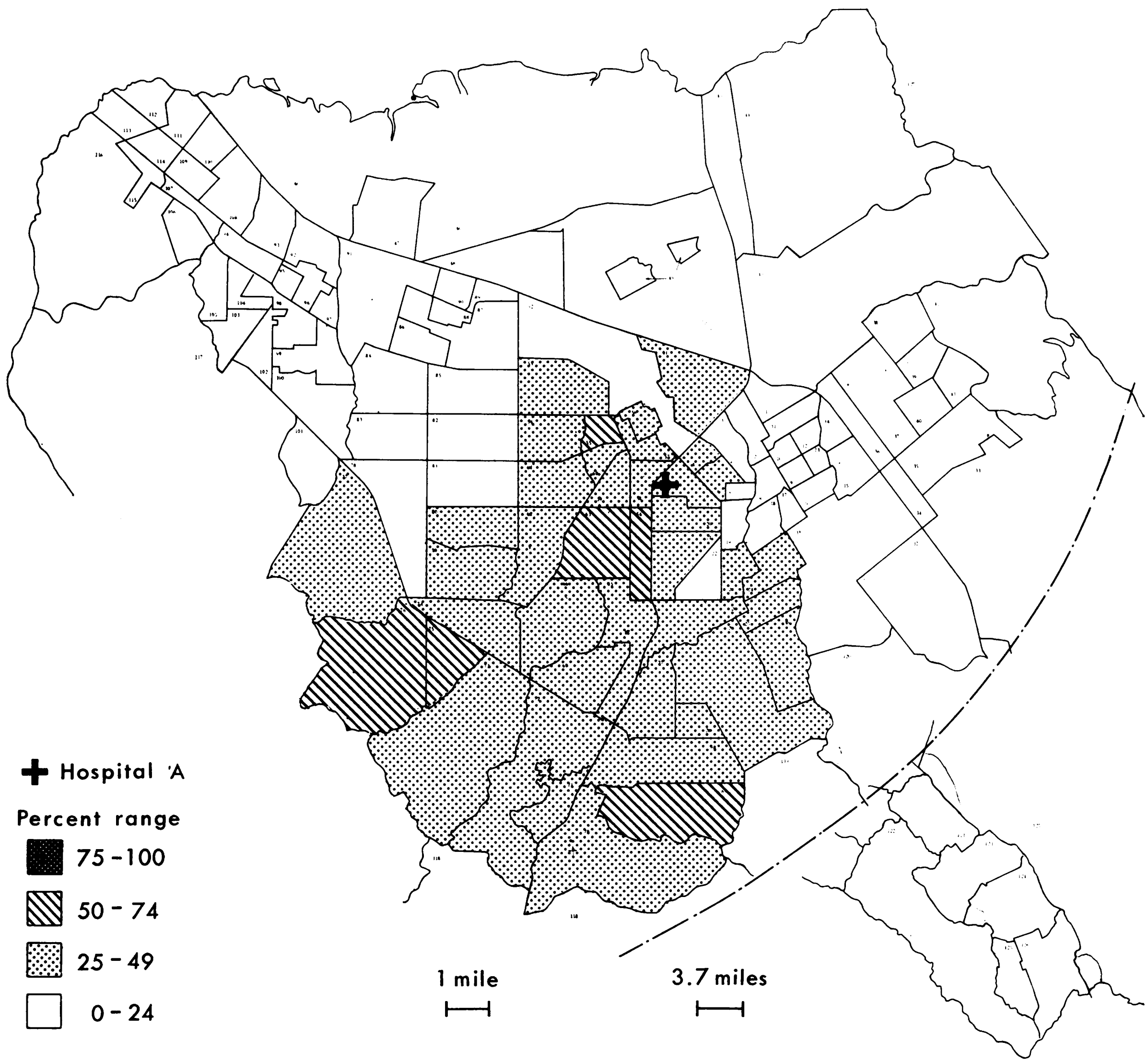


Figure 3. Enlarged portion of figure 2 showing total admissions to hospital X and total admissions to all hospitals in Santa Clara County, Calif., by census tract, 1962



EXAMPLE: In census tract 63, 268 of 1,094 residents were hospitalized at hospital X.

Figure 4. Medical-surgical admissions to hospital A as a percentage of total medical-surgical admissions to all hospitals, from each census tract, Santa Clara County, Calif., 1962

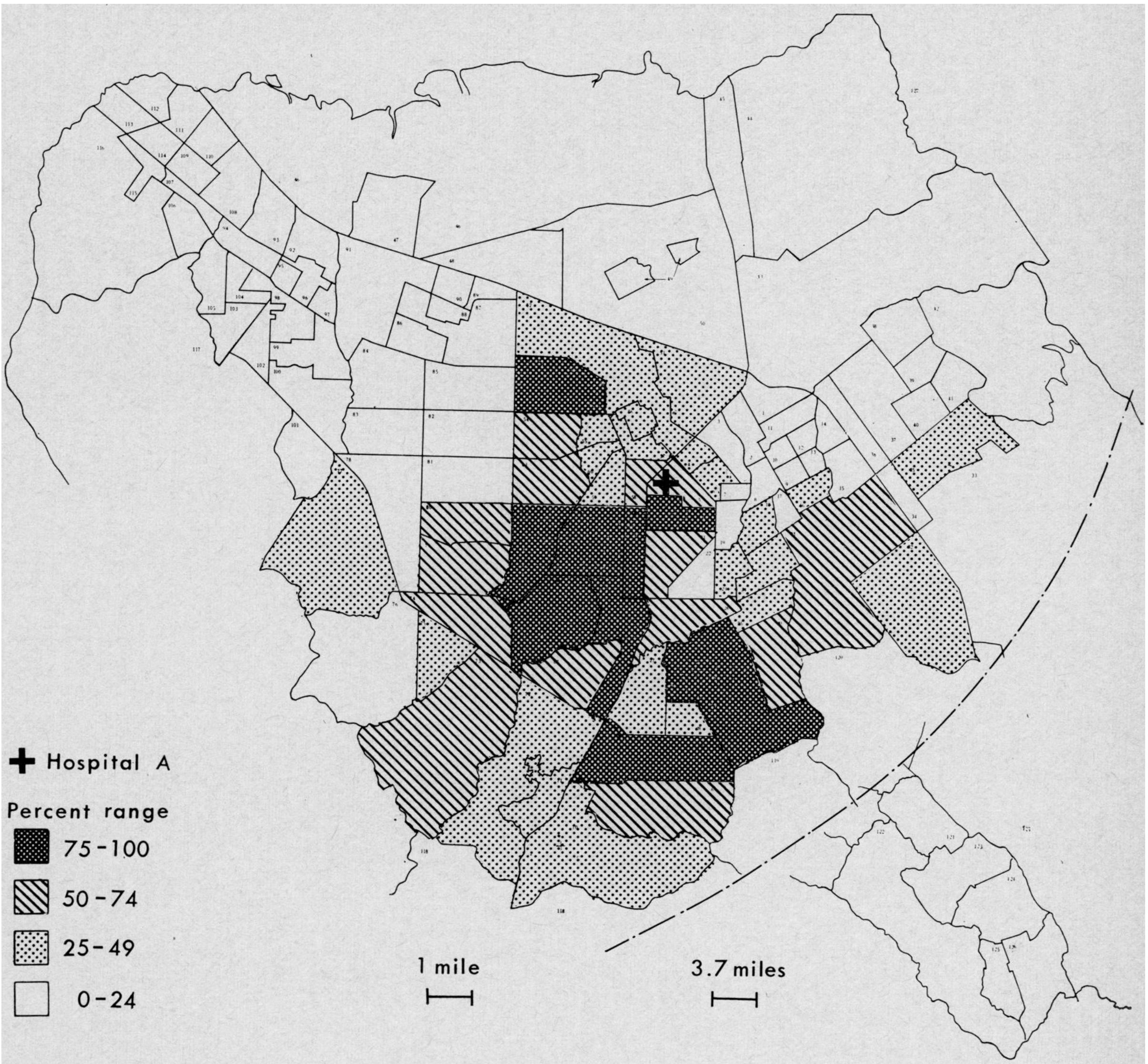


community planner may quickly scan a listing of the geographic areas in his community to see which areas are contributing most heavily to a specific patient service load. Figure 1 is an example of the output of the computer-card array program, based on approximately 80,000 admissions originating from 127 census tracts, comprising the total resident patient load dispersed among the 8 general hospitals in operation for the full year of 1962 in Santa Clara County.

It is a relatively simple matter to provide arrays for each institution showing the dispersion of total patients among the geographic areas and also to provide individual arrays indicating the distribution of admissions to the services of medicine-surgery, pediatrics, and obstetrics. From a review of such information, one can then decide which maps may be of greatest interest.

To help answer some of the questions on area relationships, the array is translated into map form. Such a device can help to indicate whether these areas are grouped centrally around a hospital, whether they follow paths such as major highways, or whether they are

Figure 5. Medical-surgical admissions to hospital A from each census tract as a percentage of total medical-surgical admissions to that hospital, Santa Clara County, Calif., 1962



located in neighborhoods where staff physicians maintain their private offices. By selecting and programing the grid coordinates to locate within each of the 127 census tracts the exact spot for the number of hospital admissions to be printed, a computer printout of spatially arranged numbers may be produced. By inserting the computer printout under a clear acetate outline of an area, a finished map is obtained. The acetate outline must be large enough to accommodate the desired computer printout for the smallest census tract. Large tracts, when grouped together, may be reduced in scale so as not to distort the basic relationships.

Figure 2 is a census-tract map of Santa Clara County with a portion of the county reduced in scale where tracts are very large. The top number printed within each tract represents the total number of resident admissions to a particular hospital. The lower line contains the total number of residents originating from the same tract who were hospitalized in the eight general hospitals for that year. Figure 3 is an enlarged portion of figure 2, more clearly displaying the printout of the two variables and the census-tract identification number.

To determine how the residents of a census tract use a specific institution, it is a simple matter to compute the admissions to this particular hospital as a percentage of the total coming from that area. For example, 268 (25 percent) of 1,094 patients residing in census tract 63 were hospitalized at hospital X. The percent or admission rate may also be one of the printout variables if such information is contained in the detail punchcards.

Figures 4 and 5 indicate suggested types of mapping to delineate hospital service areas. Figure 4 illustrates the type of example just given, based on the number of admissions (in this illustration, to the medical-surgical service) from each tract to hospital A as a percentage of the total medical-surgical admissions from each tract. The census tracts have been aggregated into four intervals. The darkest tone identifies those tracts with 75 to 100 percent of admissions to this hospital; in this instance there are none. The second interval (diagonal tone) shows tracts contributing 50 to 74 percent of all admissions to hospital A. The 25 to 49 percent range of admissions is shown in light gray, and the last range, with 0 to 24 percent of admissions, is without shading.

To show the other side of the coin, figure 5 illustrates the census-tract areas divided into intervals on the basis of their relative weights in sending medical-surgical admissions to hospital A. Here percentages are computed as the number of medical-surgical admissions to hospital A from each tract as a percentage of the total medical-surgical admissions to this hospital. Again the darkest tone identifies the first interval (75–100 percent) which depicts those fewest tracts, calculated from the bottom toward the top of an array similar to that shown in figure 1, aggregating 25 percent of the medical-surgical admissions to hospital A. The 50 to 74 percent range (diagonal tone) represents those tracts higher on the array aggregating the next 25 percent of such admissions. The last two

Comparison of manual versus computer time estimates to produce 36 arrays and 16 county maps, Santa Clara County, 1962 [1]

Manual procedure	Hours	Computer procedure	Hours
Arrays	188. 00	Arrays	113. 05
Key punch and verify source data, prepare tabulations and listings for 4 variables by 127 census tracts.	113. 00	Key punch and verify source data, prepare summary and instruction cards for 4 variables to be arrayed by 127 census tracts and number of arrays desired.	113. 00
Prepare 36 arrays: type titles, margin headings, scale, draw bars to indicate variable in relation to scale, and verify entries.	75. 00	Feed punched data and instruction cards to computer. Printout from computer includes 36 arrays complete with titles, margin headings, scale of bar charts, and bars.	[2]. 05
Maps	152. 00	Maps	32. 05
Summarized data cards supplied from manual array process (see first procedure above).	0. 00	Summarized data cards supplied from computer array process (see first procedure above).	0. 00
Prepare list of census tract variables for each of 8 hospitals.	8. 00	Prepare instruction cards for variables to be mapped, listing to check instruction errors, arrange data deck in sequence of selected grid coordinates.	5. 00
Prepare 16 maps, enter and verify figures, map titles, and legends.	144. 00	Prepare original map outline for printing, select grid coordinates for 127 areas, miscellaneous hand operations.	27. 00
		Feed punched data and instruction cards to computer. Printout from computer includes spatially arranged numbers for 16 original maps including titles and legends.	[3]. 05
Total	340. 00	Total	145. 10

[1] From data for approximately 80,000 annual admissions from 127 census tracts to 8 general hospitals.
[2] 2.57 minutes.
[3] 3.06 minutes.

intervals, with 0 to 49 percent of admissions, are similarly derived and are shown, as in figure 4, in light gray and without shading. From figures 4 and 5 it can be seen that, while a tract may be important to a particular hospital in the absolute number of cases admitted, the individual hospital may not be alone in providing significant amounts of health services to the tract.

Obviously, these are not the only considerations in studying how people seek services and how institutions serve people. By having such information in map form, it is possible and convenient to relate these patterns to the present and anticipated patterns of use of land and transportation networks.

The computer program is flexible enough to allow the printout of 1 to 100 variables within a given geographic area. The only limiting factors are the scale of the map and consequently the space available for printout. The economy, accuracy, and speed with which this material can be produced make this technique particularly attractive for hospital planning, especially in metropolitan areas.

The time cost of preparing 16 original maps including necessary processing, to be used in reproducing additional copies for distribution, was much lower by the computer process than it would have been by hand mapping (see table). The computer process for mapping, after having prepared the arrays, required 5 hours of punchcard operation and 27 hours of research staff time. It was estimated that a manual method would have required 8 hours of card processing and 144 hours of staff time. We have estimated that the computer technique would have required less than half (42.6 percent) of manual time for both arrays and mapping. When the grid coordinates and map outlines have been prepared, they need not be repeated for the community. It is quite possible that staff time could be further reduced to 8 hours in computer mapping for additional research in Santa Clara County, whereas 128 hours would still be required for manual mapping. Each array or map required an average of less than 7 seconds of IBM 7090 computer time.

There are many possible adaptations of computer techniques in public health. Continued observation of deaths associated with specific chronic diseases (for example, respiratory) could be related to the individual's place of residence or employment. These data could then be correlated with air-pollution studies where high- and low-count pollution areas are of interest. In followup, repetitive mapping of areas would be required to indicate variation of air samples in the pollution areas.

Similarly, the field of environmental sanitation is concerned with necessary bacterial counts in rivers and streams over periods of time. This type of count might be maintained on a current basis by defining the reading stations and mapping the data by computer to display time-interval changes in bacterial counts for the entire waterway.

The volume of detail in analysis for a large number of variables would be impossible to accomplish without computer techniques. Analysis is greatly aided by having such statistical material available in map form, but great expense and time would be required for drafting by hand. With a computer the investigator is in a position to make more prompt and thorough analysis than hitherto has been possible. The use of computer techniques creates the ability to summarize quickly and portray health and related information economically on any areal basis.

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