The Availability of Physician Services: A Geographic Analysis

Paul Wing and Christopher Reynolds

This article describes a new technique for estimating the availability of physician services in small geographic areas. Given counts or estimates of the number of physicians practicing in small geographic areas (e.g., zip codes), the technique allocates a portion of the services of each physician in an area to his home area and to nearby areas in proportion to both the propensity of patients to travel for medical care and the availability of potential patients. The longer the time required for a patient to travel to the physician, the smaller the proportion of the physician's services allocated to the patient's area, with the precise relationship determined by a special analysis. The final estimate of the availability of physician services in each small area is the sum of the service proportions of every physician in all of the small areas. The total supply of physician services is the same as the original total, but the distribution is adjusted to reflect the time that patients are willing to spend traveling to obtain medical care. Although this technique requires considerable data processing, it permits more accurate estimation of the supply of physician services in small geographic areas than is possible with traditional methods. It better represents the probabilistic and interpenetrating nature of physician service areas than alternative techniques and appears to be particularly applicable in estimating the supply of primary care physician services. Actual data for pediatricians and children in northeastern New York using zip codes as the geographic units illustrate the technique. Limitations, applications, and possible extensions are discussed.

The supply of physician services continues to be a topic of interest among planners, policymakers, and practitioners with responsibilities

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This project was supported in part by a grant from Norstar Bank of Upstate New York as Trustee for the Frederick McDonald Trust.

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for the delivery of health care. This attention is ultimately based on concerns of the general public and elected representatives about whether the health care needs of society are being adequately served (Iglehart 1986; Newhouse et al. 1982; Sloan 1977). There may also be reason for concern based on evidence that a more than sufficient supply of physicians could result in excessive health care costs (Davis 1982; Hemmenway and Fallon 1985; Wennberg and Gittelsohn 1982).

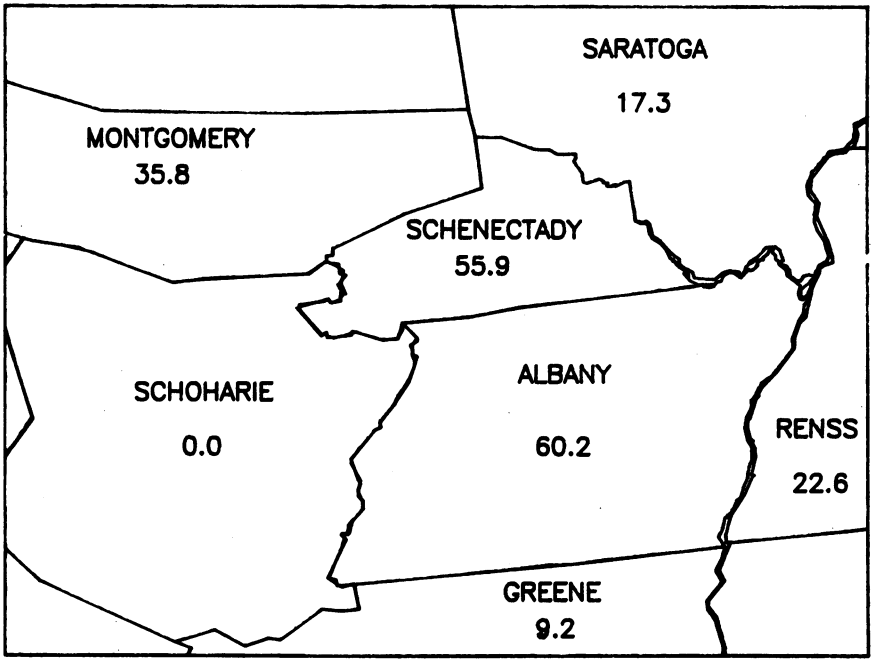
The study of physician supply and requirements most often cited in recent years has been the report of the Graduate Medical Education National Advisory Committee (GMENAC) (1980). Although GMENAC predicted a surplus of physicians nationally in the aggregate, it also reported that medical specialists were unevenly distributed, which could result in inadequate access to medical services for significant numbers of individuals in certain geographic areas. Unfortunately, as GMENAC pointed out, inadequacies in the methods used to identify the location of medically underserved populations have hampered the formulation of effective health manpower policy to improve access to physician services.

The most common method used to determine the location of medically underserved populations has been to compare actual and "ideal" physician-to-population ratios within specific, predefined geographic units. To evaluate the adequacy or inadequacy of the supply of physician services within a geographic unit, the "ideal" ratio is multiplied by the population within the boundaries of the unit to provide an estimate of the "ideal" number of physicians needed to serve the area. This number is then compared to the actual number of providers practicing in the area to determine if the supply is adequate.

This approach has been used widely in analyzing the supply and distribution of physicians (Gamble et al. 1983; New York State Education Department 1983; New York State Department of Health 1984). Physician shortage areas identified using this technique have been the basis for numerous federal and state programs for alleviating physician shortages in recent years.

Unfortunately, simple ratio methods provide distorted results because geographic units with definite boundaries are used in the analysis. The problem can be illustrated with the map in Figure 1, which shows pediatricians per 100,000 for population ages 17 and under in selected counties in northeastern New York. This map is based on the traditional method of partitioning populations into geographic units along geopolitical boundaries, in this case counties. It shows a relative abundance of pediatricians in Albany County and none at all in Schoharie County, which lies directly to the west. The problem is brought

Figure 1: Pediatricians per 100,000 Children, Based on County Statistics on Population and Children



into focus by considering two hypothetical homes, one in Schoharie County and one in Albany County, each just across the county line from the other. Presumably, each home has essentially the same access to pediatric care even though the map implies very different levels of access. Similarly, if a pediatrician's office sits on a road in Albany County a short distance from the Schoharie County border, one can ask whether services provided by the pediatrician to children in Schoharie County are accounted for adequately.

Simple physician-to-population ratios like those in Figure 1 have been used by many analysts because the underlying concept is simple and easy to explain and because physician and population data are readily available for a variety of geopolitical units. In their examination of ambulatory medical care, Kleinman and Makuc (1983) have clearly shown the problems that can arise in this approach due to the migration of patients across geographic boundaries. In essence, the physicians represented in the numerator of the physician-to-population ratio for a particular geopolitical unit typically serve more people than

are counted in the denominator; and, conversely, the people counted in the denominator may receive their care from physicians outside the geopolitical unit in which they reside.

Ideally, one could identify physician service areas so that the physician counted in the numerator of a physician-to-population ratio would serve only the population counted in the denominator, and the population in the denominator would consume only the physician services represented in the numerator. Brooks (1978) has discussed the difficulties of achieving this ideal, as well as a number of other problems in assessing the sufficiency of the supply of physicians.

In an effort to assign the denominator of physician-to-population ratios more accurately, some studies (Gamble et al. 1983; New York State Department of Health 1984; Hindle et al. 1978; Makuc, Kleinman, and Pierre 1985) have clustered geopolitical units in an attempt to approximate physicians' actual service areas. Although this approach is an improvement over analysis based on arbitrary geopolitical units such as counties, the results are still confounded by significant migration of patients across the borders of the geographic units. Even if the original geographic units are small, simple aggregations of them, even those based on patient origins or sociological characteristics, will not adequately address the migration problem. This is because medical service areas in *any* health care system allowing freedom of choice for patients are not discrete, self-contained geographic units; they are probabilistic and interpenetrating (Shannon, Bashshur, and Metzner 1969).

A New Method for Estimating the Availability of Physician Services

The technique described here does not rely on nonoverlapping geopolitical units or aggregates. Instead it develops implicit physician service areas that are probabilistic and interpenetrating to yield estimates of the supply of physician services in small geographic subdivisions that are likely to be more accurate than those generated by traditional ratio methods.

The technique does not deal directly with the problems of detecting or correcting physician shortages or assessing the adequacy of services in an area. It merely provides a mechanism for developing more accurate estimates of the supply of physician services in the area.

Once prepared, these estimates can be used by planners and policymakers in a variety of ways to evaluate and promote changes in the delivery of services.

This approach to estimating the supply of physician services is unique because it incorporates travel time as a cost factor that limits the geographic distribution of individual physician services. It is also unique in that it apportions physician services to small geographic areas in fractional physician equivalents.

To simplify the discussion, the procedures are often described in terms of a single physician. It is a simple matter to aggregate the results for many providers to obtain an accurate picture for all.

A number of enhancements have been incorporated into the illustrative analyses presented, for example, the exclusion of non-patient-care activities of physicians. These adjustments improve the accuracy of the resulting estimates but are not essential to the new estimation method.

BASIC CONCEPTS AND DEFINITIONS

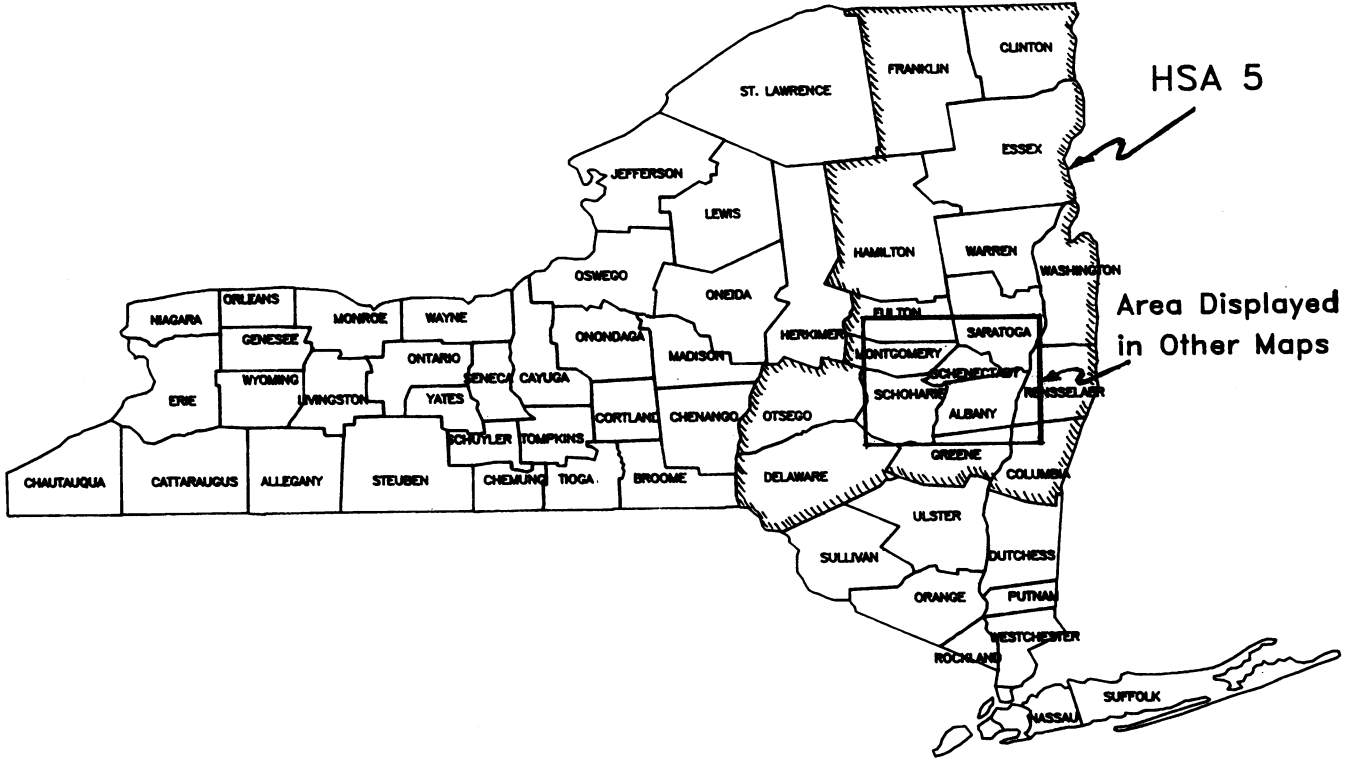
One of our premises is that it is appropriate to distribute different types of medical services based on different criteria. This permits the development of different service areas for different types of physicians, depending on the nature of the medical services provided. For example, factors that determine the geographic distribution of primary care services are likely to be very different from those for surgical services. For this reason the analysis described here is limited to the services that pediatricians offer to children ages 17 and under. To illustrate the development and utility of this approach to the identification of medically underserved populations, physician and population data from the 17 counties in northeastern New York state have been used. This region, which is shown in Figure 2, is one of the eight federally designated Health Systems Agencies in New York.

GEOPOLITICAL UNITS FOR THE ANALYSIS

A number of different geopolitical units could be used in this analysis, including counties, census tracts, minor civil divisions, and zip codes. Although all of the data used by the new technique are generally available for counties, these areas are too large to be useful. The resulting physician supply estimates would be no more accurate or useful than the ones shown in Figure 1.

Census tracts would be excellent for this purpose. They are small and well defined, and their geographic boundaries are easily obtained.

Figure 2: New York State, Showing Health Systems Area 5



Unfortunately, data on physicians are generally not available for census tracts, which would necessitate a significant coding effort, especially for urban areas. As a result, few of the data necessary for a meaningful analysis are readily available for this geopolitical unit. Another minor disadvantage is that their large numbers would add to computational burdens.

Minor civil divisions (MCDs) such as townships and villages are also candidates for the geographic subunits of analysis. MCDs are the basis for the Primary Care Analysis Areas developed by the New York State Department of Health (1984). Significant problems for MCDs often arise in urban areas where they are either undifferentiated or defined by specific street addresses. This means that analyses for urban areas based on MCDs are either unreliable or laborious to implement.

U.S. Postal Service zip codes were chosen as the geographic subunit for this study because their relatively small size allows good geographic resolution and, equally important, because basic data about physicians, populations, and geographic boundaries are readily available for zip codes. Supplementary data about doctors and patients can also be easily compiled or collected according to zip code.

Despite their advantages over alternative geopolitical units, zip codes are by no means free of problems. Many of the difficulties they present are related to the fact that the U.S. Postal Service has developed them only to define delivery areas for mail; they change them occasionally with no regard to research studies that may be based on them. Old zip code lists and boundaries are not maintained. Many zip codes are completely unrelated to medical care and demographic data, although commercial vendors do provide significant amounts of data for zip codes. Some "point zips" are for small rural post offices that have only a set of boxes for mail pickup. Many in urban areas are for office buildings or government subdivisions that are unrelated to either physicians or potential patients. Despite these "technical problems," zip codes can be used with relative ease once the anomalies have been addressed.

Although the forthcoming discussion and illustrations refer only to zip codes, the technique could be implemented with any other geographic unit deemed appropriate by the user. The only requirements are that the units chosen be small enough to provide adequate resolution for the intended analyses and displays and that the necessary data be available for the chosen units.

DATA REQUIREMENTS

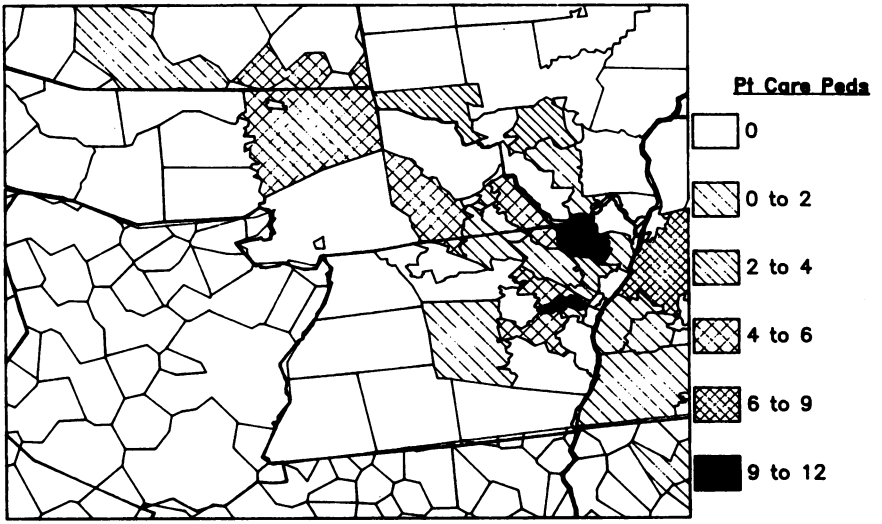
Several types of data are required to implement this technique. One must have a count of physicians for the medical specialties under study—and, optionally, the proportion of time each physician devotes to patient care—for each zip code in the geographic region of interest. We obtained the counts of pediatricians used in this study from an inventory of physicians developed at the Albany Medical Center (AMC) for a variety of planning purposes. The AMC inventory, based on official New York state physician licensure records, was modified by reference to other data sources, including the Yellow Pages, files of the Albany Medical College, and area third party payers. The data on pediatricians were further adjusted in collaboration with the Department of Pediatrics at Albany Medical College to reflect pediatricians' patient care work loads. By excluding efforts of pediatricians devoted to teaching, research, administration, and other non-patient-care activities, more accurate estimates of available pediatric services can be obtained. The results for selected zip codes in northeastern New York are shown in Figure 3.

Data on potential patient populations by age and gender must also be available. The New York State Department of Commerce provided the 1980 census data disaggregated by zip codes and age groups used in this analysis.

A data base containing the travel times between all pairs of zip codes in the region under investigation is necessary. The data used in this study were derived from maps and computer files maintained by the New York State Department of Transportation. A single node (street intersection) was chosen to represent as closely as possible the geographic center of each zip code. The travel-time matrix was then generated containing the number of minutes it takes to travel by automobile from each node to each of the other nodes in the region. For northeastern New York this resulted in a 465 × 465 matrix of travel times. (Similar information should be available for most other states, although we have not attempted to verify this.)

To prepare these computerized maps, a file containing the boundary coordinates for all the zip codes in the region is needed. Such boundary files are available from commercial vendors and companies that market computer mapping software. While the maps are not essential to the analysis, they do greatly simplify the task of displaying and interpreting results.

Figure 3: Patient Care Pediatricians, Based on Zip Code of Practice Location



ESTIMATION OF PHYSICIANS' SERVICE AREAS

Because this new technique allocates the services of physicians to zip codes other than the ones in which they practice, it is useful to describe briefly the allocation process. A fraction of each physician's patient care services is allocated to several zip codes in proportion to two factors that define the expected availability of the physician's services: the demonstrated willingness of patients to spend time traveling to a doctor's office and the distribution of the potential patient population relative to the doctor's office. Thus, the share of a physician's services allocated to a zip code is proportional to the number of potential patients in the zip code and inversely proportional to the amount of time it takes to travel to the physician from the zip code. In effect, the procedure creates an implicit boundary for the service area of each physician based on the maximum time patients are willing to travel.

The relationship between travel time and use of physicians' services was chosen as the basis for the geographic index of market demand because travel time has been shown to be a factor that restricts access to, and thus utilization of, health care services (Phelps and Newhouse 1974; Shannon, Lovett, and Bashshur 1979). Distance could be used instead of travel time (Williams et al. 1983; Kane 1969), but travel time was deemed to be the more appropriate measure.

TRAVEL TIMES TO PHYSICIAN OFFICES

To quantify the relationship between travel time and market demand in this study, a small, nonrandom survey of 578 parents of pediatric patients was conducted regarding their journey to one of five pediatrician's offices in urban and suburban areas of Albany, Schenectady, Rensselaer, and Saratoga counties. Shortly after arriving at the pediatrician's office, the parents were asked their usual mode of transportation to the pediatrician's office and how many minutes it typically took to travel from their usual point of origin. This information was used to develop a mathematical model representing the willingness of patients to spend time traveling to the pediatrician's office. This model was the basis for one of the factors used to distribute a fraction of each pediatrician's services to each zip code of the pediatrician's potential patient population.

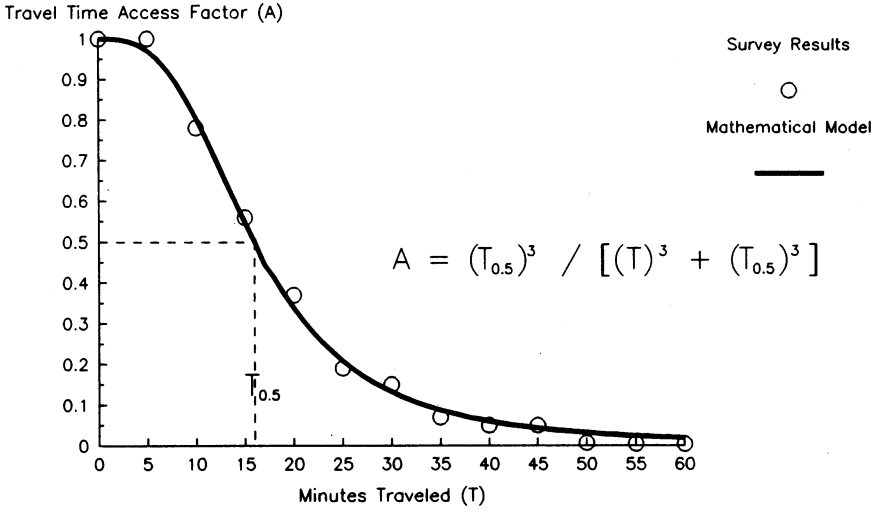
The next step in the process was to develop a matrix of travel times between the 465 zip codes in the region. This matrix, which was developed with assistance of the New York State Department of Transportation, contains the shortest driving times between all pairs of zip codes in the region under average traffic and weather conditions. Since one of the premises of the study is that consumers will generally attempt to minimize time spent in travel to the physician's office (Phelps and Newhouse 1974), this shortest travel-time matrix seems appropriate for the task. Because all of the population and physician data are keyed to zip codes, this travel-time matrix can be used to estimate the travel time from the zip code of any population group to the zip code of any physician office.

Although conceptually straightforward, this aspect of the study involves substantial data manipulation and computer analysis.

GEOGRAPHIC PRESENTATION OF DATA

One of the advantages of this new technique is that it coordinates nicely with mapping capabilities now available for microcomputers. Minor problems may arise that do not affect the mapping process itself. For example, the resolution of the boundary files may be greater for some areas than for others, and boundary files prepared by different vendors may not overlap exactly. Both problems are present in the maps shown in this article, although they do not detract from the usefulness of the results.

Figure 4: Travel-Time Survey Results (fraction of respondents that traveled at least the specified number of minutes)



Source: Albany Medical College Survey of Parents of Pediatric Patients, 1985.

RESULTS

Two types of results are presented. The first are the findings from the survey used to estimate the travel-time patterns for pediatric patients. The second is the estimation of the equivalent pediatrician services available in different zip codes in a section of northeastern New York.

TRAVEL-TIME SURVEY

The responses to the survey about how much time it took parents to travel to the pediatrician's office are presented as the small circles in Figure 4. The figures represent the 96 percent of the 578 respondents to a small, nonrandom sample of parents who brought their children to the pediatrician's office by automobile. The responses of the remaining 4 percent (23 parents) who came on foot were excluded from the analysis because the travel times used in the basic methodology are based on automobile travel only. Although the survey's use is limited because random sampling was not used, the results appear to be appropriate for this pilot test of the estimation technique. Figure 4 also shows the curve generated by the mathematical model fitted to the survey data. The model, which bears a close resemblance to gravitational models some-

times used in travel-time analysis (Shannon, Bashshur, and Metzner 1969), is:

$$A = (T_{0.5})^n/[(T)^n + (T_{0.5})^n]$$

where

A = travel time access factor—the proportion of patients who traveled at least time T to reach the doctor's office.

T = reported length of time spent traveling to the pediatrician's office.

$T_{0.5}$ = median travel time.

n = parameter for adjusting the shape of the curve.

In developing the model the value of n was selected to make the curve match the data as closely as possible. This permits the curve to be used to calculate the travel time access factor for any arbitrary value of T. This is very convenient during the later stages of the analysis, which involve a great many calculations of this factor for travel between different pairs of zip codes.

Ideally this model would have been based on a more extensive survey, involving not only patients who actually visited a pediatrician, but also some who did not. It would be desirable to account for differences among rural, urban, and suburban areas, as well as for transportation modes other than automobiles. The fact that some individuals may be willing to travel farther in one direction than another might also be incorporated. All of these possibilities were beyond the scope of this modest study.

Despite its limitations, the model that resulted from our analysis provides the basic relationship necessary to test the new physician-supply estimation technique. The relationship between travel time and willingness to travel to a physician's office shown in Figure 4 is also intuitively correct and relatively easy to implement in subsequent stages of the analysis.

ESTIMATION OF EQUIVALENT PHYSICIAN SERVICES

The fraction A of the parents who demonstrated willingness to spend at least T minutes in travel to use a pediatrician's services was taken as an index of the probability of consumption of a pediatrician's services in relation to travel time T. This index was applied to the zip code-to-zip code travel-time matrix to calculate the probability of consumption of each pediatrician's services by the population in each zip code in the

region. The probability assigned to each zip code was then divided by the sum of the probabilities for all the zip codes to yield the normalized probability of consumption of a pediatrician's services by the population at each zip code. Since this normalized access factor A is an indicator of each zip code's share of the physician's services, it can be used as a basis for apportioning the pediatrician's patient care services to the zip codes in the region.

Physician services cannot be allocated solely on the basis of travel times to different zip codes—the location of potential patients' residences must also be considered. For this reason the model was designed to account for the distribution of potential patient populations when estimating the geographic availability of a physician's services.

If each potential patient is taken as one unit of demand, then the proportion of a physician's services available to the population in a zip code is related to the population size in that zip code, P_z. This population can then be multiplied by the respective travel-time access factor for the zip code A_z, to get an index of the access-weighted, population-based demand for a physician's services. This demand factor can then be normalized by dividing by the sum of all the products $(A_z)(P_z)$ to yield a new factor that represents the fractional demand-based market share of a physician's service area. This factor may then be used to distribute the physician's patient care services over the service area in proportion to each zip code's fraction of total demand for the physician's services:

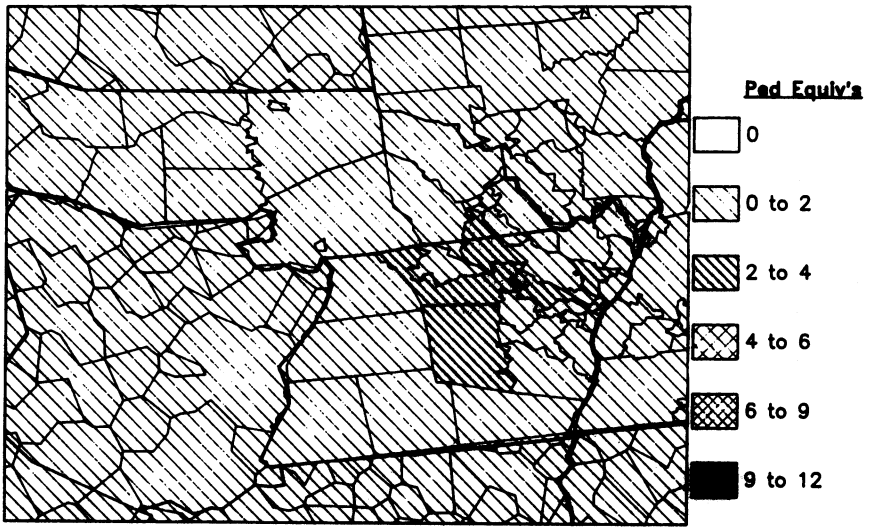
$$S_z = (A_z)\ (P_z)/\Sigma[(A_i)(P_i)]$$

The distribution of pediatrician services after application of this technique using actual data for pediatricians and children in northeastern New York is shown in Figure 5. This adjusted distribution is significantly different from the raw data displayed in either Figure 1 or Figure 3, even though the total volume of pediatric services is the same for the entire region.

DISCUSSION

This method of estimating the availability of physician services has considerable promise for use in medical manpower planning, particularly for primary care physicians whose patients generally travel by automobile. Although the technique does require more effort than the simple counting used in traditional methods, much of this can be accomplished with the help of readily available microcomputers and

Figure 5: Pediatrician Equivalents Adjusted for Location of Children and Travel-Time Access Factor



software. The greater accuracy and insights afforded by the technique are likely to be worth the additional effort for those serious about understanding access to physician services.

The proposed technique does not eliminate uneven distribution of physicians but merely allocates to nearby zip codes a portion of the services available from each physician. In practice, those zip codes with large numbers of physicians will probably still show relatively large equivalent physician services, but some of the services will be allocated to other areas as well.

LIMITATIONS

Because the technique cannot distribute the services of a physician beyond the outer limits of the geographic data base, estimates of the availability of physician services will be artificially elevated in the zip codes near the outer borders of the area of analysis. For this reason, conclusions about access to physician services for zip codes close to the borders of the region may not be accurate. This can be overcome by extending the area of analysis to include zip codes beyond the boundary of the region, if appropriate data on physicians, population, and travel time are available.

Another limitation may arise if there are significant variations in

the travel-time cost function by physician specialty or geography. For example, patients in rural areas may be willing to take more time traveling longer distances to see a physician than those in urban areas. It may also be that patients are willing to spend more time traveling to see one type of physician than another. Special consumer surveys would have to determine whether such differences exist. If they are detected, various travel-time cost functions could be developed for each region or specialty and incorporated in the technique.

The use in the model of travel only by automobile would limit the model's usefulness in many urban areas where public transportation and walking may be preferred to driving. This too would have to be addressed in a special survey of some sort.

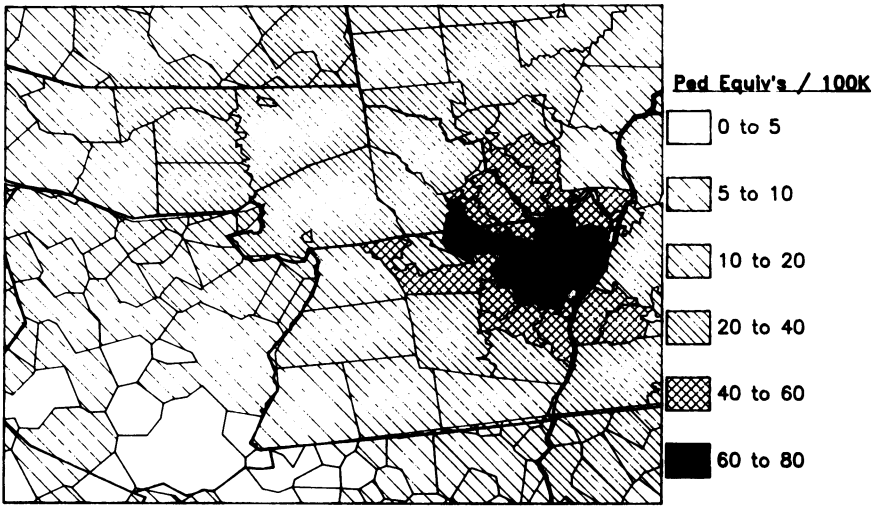
DETECTION OF MEDICALLY UNDERSERVED AREAS

One of the principal concerns of health provider supply planners is estimating the needs for additional primary care physicians in underserved areas. The estimated supply of physician services shown in Figure 5 is a composite for all pediatricians in northeastern New York constructed using the technique described. These equivalent physician counts can be incorporated into a ratio method for assessing the adequacy of the supply of physician services by dividing the estimated available physicians in each zip code by the corresponding number of potential patients. Figure 6 shows the results of this analysis, which could be used to assess the adequacy of the supply of pediatrician services in the zip codes after the services have been distributed among the zip codes using the previously described technique.

The scale in this map includes the "ideal" pediatrician-to-population ratio (40 pediatricians to 10,000 children ages 17 or under) used by the American Academy of Pediatrics in their analyses of pediatrician manpower. This level of supply is attained only in the urban areas of the region. At the other extreme, the white areas on the map are zip codes with fewer than five equivalent pediatricians per 100,000 children. These areas may deserve special attention by planners and policymakers concerned about access to pediatric services.

Of course, even the use of physician supply estimates prepared using the new technique will not account for special medical needs or social circumstances of potential patients in particular zip codes. To do this, one must incorporate other factors into either the physician service model, or more likely, into the population component of the ratio. Possible adjustments have been discussed (New York State Department of Health 1984; Hadley 1979) and include modification of physi-

Figure 6: Pediatrician Equivalents per 100,000 Children, Based on Data in Figure 5 and Counts of Children in Zip Codes



cian estimates derived using the technique to reflect a variety of local demographic factors and relationships, such as morbidity and mortality; prevalence of disease; income levels and ability to pay; and the age, cultural, and sex structure of the population. GMENAC (1980) commented on the difficulty of choosing an ideal ratio, indicating that ratios might vary from region to region based on specific health care needs and demands of resident populations. A panel of local health experts might be required to develop the necessary adjustment parameters.

POSSIBLE EXTENSIONS

Several types of extensions to this basic technique are possible. It could be used for primary care specialties other than pediatrics if the necessary data were available, or for nonprimary care specialties, although differences in travel patterns and consumer behavior for acute care may require significant modifications to the approach. In addition, the technique could be used for other states. The necessary data, including travel-time data similar to those used to generate the zip code-to-zip code travel-time matrix in this study, are apparently available in most states.

Another, more ambitious, extension would create a composite index of the availability of all types of primary care services, including

those provided by physician extenders and special ambulatory clinics. One of the major difficulties is sorting out the different types of primary care provided by different types of physicians to the same potential patients. For example, although pediatricians generally serve patients under the age of 18, some teenage women may also see gynecologists for annual checkups. The problem, then, is to determine the most appropriate way to count or allocate both physicians and potential patients—in this case, pediatricians and gynecologists and young women—in ways that will properly match the providers and consumers of primary care services. Only if this is done can appropriate ratios be developed for use by planners and policymakers.

This task will be confounded by the wide variations in practice patterns of different types of primary care practices. Special problems arise for physicians who split their practices among several sites, as is the case in many rural clinics these days. The difficulties would be compounded if primary care services provided by surgeons and other physicians usually associated with referrals and acute care are considered. These problems are probably technically tractable, assuming that the necessary data are available for analysis. They may, however, present significant practical problems.

This technique could also be used as a partial basis for identifying physician shortage areas. Physician-to-population ratios, if developed using the described techniques and adjustments, would be a much more reliable basis for assessing the adequacy of physician supply than the simple ratios used in most current studies. It would even be possible to develop an algorithm based on the proposed technique to locate a site(s) for new physicians that would raise "physician per capita ratios" to acceptable levels in an optimal way. Although this would not guarantee that physicians could be induced to locate their practices in optimal sites, it would help to identify logical new-practice sites that account for travel time of potential patients.

One final extension involves the substitution of projections for the historical data used in this analysis; this obviously would be of considerable interest to planners and policymakers, although it may place a strain on those who provide the base data.

SUMMARY

A technique has been described that appears to be more appropriate than traditional counting methods for estimating the availability of primary care physician services in small geographic areas. By incorpo-

rating the implicit travel costs that cause people to limit the time they are willing to travel for primary care physician services, the technique provides much more realistic estimates of physician availability for areas as small as zip codes. Although the technique does require more data and analysis than traditional physician-to-population ratios, computers can be used to reduce the additional computational burdens. The resulting estimates of the availability of physician services are likely to be much more realistic than simple physician-to-population ratios. Maps summarizing the results can be useful in informing those who might use the data about areas that may be inadequately supplied with physician services.

ACKNOWLEDGMENTS

The assistance of the New York State Department of Transportation and Maureen Jussen of the Department of Pediatrics at Albany Medical College are gratefully acknowledged. The comments of three referees were also very helpful.

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