Estimating the Need for Additional Primary Care Physicians

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A systems approach is used to assess the primary health care delivery system in Indiana. The output (office visits) of primary care physicians is estimated and compared with the demand for their services. Indexes of demand, supply, cost, and need are derived and used to determine the additional number of primary care physicians needed in each area. The results of this study are being used to encourage graduating medical students to practice in areas in need of additional primary medical care.

Primary medical care has become an area of concern because of the apparent decrease in the number of primary medical care providers, especially general and family practitioners, in the United States and specifically in the state of Indiana [1–3]. A technique was developed in this research to assess the primary health care delivery system in Indiana and to provide information regarding the need for additional primary care physicians in different areas of the state.

Discussions between systems analysts at Purdue University and physicians at the Regenstrief Institute for Health Care revealed that in order for the model to be useful, its parameters would have to be estimated from actual data. Thus the modeling process was constrained by the availability of data, precluding, for example, consideration of the effect of financing mechanisms such as Blue Cross/Blue Shield, Medicare, and Medicaid. A discussion of these modeling issues can be found in Standridge, Pritsker, and Delcher [4].

Methodology for Assessing Primary Medical Care Service

Primary Medical Care Service Areas

Researchers in Indiana [5,6] have described the distribution of primary care services by using ratios of population per primary care

This research was supported by the Regenstrief Institute, a division of the Regenstrief Foundation, Inc., Indianapolis.

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0017-9124/78/03029015/$02.00/0

physician in a county. However, a political unit like a county may not accurately represent a medical service area since it is possible for cities of substantial population to be located relatively close to a county line, thus providing medical care to residents of contiguous counties, or for physicians to be located within easy access of people from another county.

In this study, primary medical care service areas are defined as population centers and their environs, specifically, towns or cities with populations of at least 2,000 (the approximate number of people per primary care physician in the United States [7]) plus the people in the immediate environs of these towns or cities. The environs are defined as the area within a five-mile radius of the town or city since that is a reasonable distance to travel to a physician. If the boundary drawn around the city overlaps that of another city, a combined service area results. According to this definition, Indiana contains 79 primary care areas. The state's counties are grouped into 12 districts, each of which is divided into primary care centers and the residual rural area surrounding the centers (see accompanying figure, p. 292).

Estimating the Capacity of the Full-Time Primary Care Physician

A full-time primary care (FTPC) physician is defined as a general or family practitioner in the age group 35–39, which has the highest output in terms of visits per year for this specialty [8]. (Tables 1 and 2, p. 293.) Primary care physicians are considered to comprise nonfederal, office-based physicians, both medical and osteopathic, who are general and family practitioners, pediatricians, internists, obstetrician-gynecologists, or general surgeons. The output of one FTPC physician is defined as the number of primary care visits per year for a general or family practitioner in the age group 35–39. The output of physicians with other age and specialty characteristics is expressed as a percentage of the output of the FTPC physician. Visits per week and weeks practiced per year by an FTPC physician were computed from *Reference Data on the Profile of Medical Practice* (1972–74) [9–11] and were 183.7 and 47.7, respectively. The product of these numbers, which is the annual output of an FTPC physician, is 8,762 visits per year.

Potential demand is defined as the need for primary health care as perceived by the population, disregarding factors that would interfere with satisfaction of that need [12,13]. This is the demand the population would place on the providers of primary care if the cost of obtaining such care, both monetary and nonmonetary, were zero. Expressed demand is defined as the amount of medical services actually sought by the population. This demand is backed up by an ability and willingness to pay not only the cost of the health care itself but also other costs incurred in procuring the care [12–14].

The ideal population is defined as having full geographic accessibility and no economic barriers to primary care, which implies that all of its potential demand is expressed and all of its expressed demand is satisfied. The yearly demand rate for the ideal population is estimated from the yearly number of visits made by those with family

Primary care service areas in Indiana.

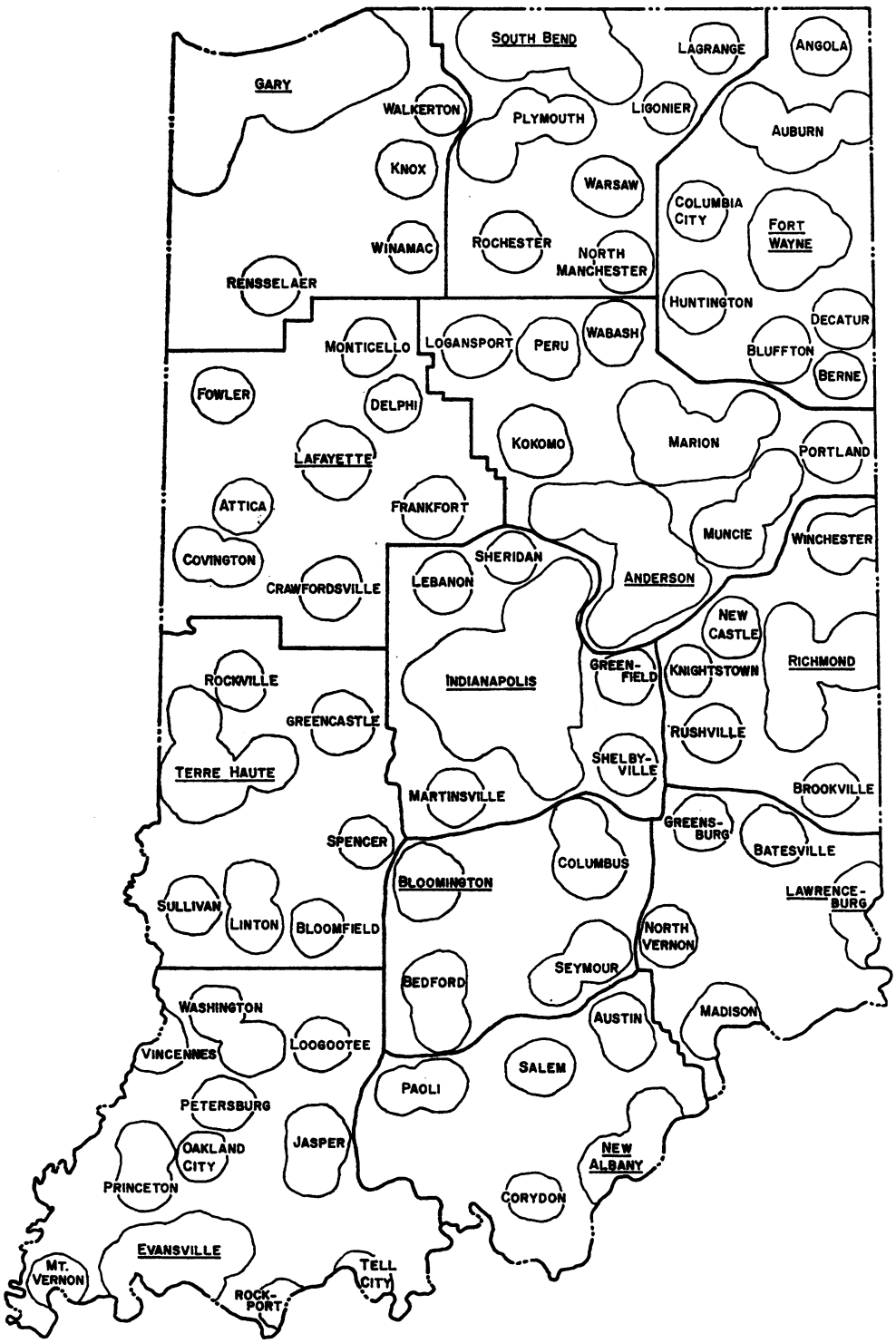

Table 1. Relative Number of Primary Care Visits for Different Specialties

Specialty	Visits/ day*	Weeks/ year†	Relative visits/ year
General and family ..	39.51	47.73	1.000
Internal medicine	20.95	47.20	0.524
Pediatrics	36.51	47.77	0.925
Obstetrics-gynecology .	27.34	47.70	0.692
General surgery	18.73	47.03	0.467

* Estimated from Delcher, Raykovich, and Murray [19].
† Estimated from *Reference Data on the Profile of Medical Practice* [9–11].

incomes of $15,000 and over since it is assumed that this income group has all of its expressed demand satisfied and would be able to bear the full monetary cost of receiving care. In 1971 people in this income group visited all physicians at the rate of 5.1 visits per year, and, of these, 3.0 visits were to primary care physicians [15].

For the purposes of this study, the ideal population is also defined as having demographic characteristics similar to the population of Indiana and it is assumed that geographic accessibility to primary care (percentage of the potential demand that is expressed after allowing for the cost and inconvenience of traveling to a physician) for this group is the same as the average geographic accessibility for Indiana, which was established as 0.9373. The demand rate for primary care for the ideal population can then be calculated as 3.0/0.9373 or 3.20 visits. Therefore the yearly capacity of an FTPC physician is 8,762/ 3.20 or 2,700 individuals of the ideal population. With this information, an algorithm has been developed for obtaining indexes of primary care delivery for the previously defined service areas.

Table 2. Relative Number of Visits Attended by General and Family Practitioners of Different Age Groups
(Source: Standridge et al. [8])

Age group	Relative visits/ year
Under 35	0.812
35–39	1.024
40–44	0.958
45–49	0.892
50–54	0.825
55–59	0.759
60–64	0.693
65–69	0.626
Over 69	0.527

Algorithm for Determining Primary Care Service Index

1. Calculate the Equivalent Number of FTPC Physicians in Each Service Area. The visits attended by each physician can be expressed relative to those attended by the FTPC physician as a function of age and specialty [8–12,16–18]. For comparison among specialties (Table 1), the number of visits attended per day is estimated from the Delcher, Raykovich, and Murray study of Indiana physicians [19]. The weeks worked per year are estimated from *Reference Data on the Profile of Medical Practice* [9–11]. The days worked per week are assumed not to vary by specialty.

Similarly, the output of physicians can be compared among age groups. Standridge et al. [8] report relative values for general and family practitioners in Indiana (Table 2). Age and output are assumed to be independent of specialty because the available data do not allow estimation of the relationship between age and output as a function of specialty.

The output of each physician in a service area, expressed as a percentage of the output of the FTPC physician, is computed as the product of the relative number of visits of those in the specialty and the relative number of visits of those in the age group of that physician (see Tables 1 and 2). Then, the number of FTPC physicians in a service area is the sum of these products for all the physicians in that area.

Physician extenders, that is, physician assistants and nurse practitioners, are not included in the model. Standridge [1] estimated that these providers supplied less than 0.3 percent of the primary care visits in Indiana in 1975. However, it would be easy to extend the model to include these providers of primary care.

2. Compute a Geographic Accessibility Measure. Geographic accessibility is defined as the percentage of the potential demand that becomes expressed demand after allowing for the cost and inconvenience of traveling to a physician. The accessibility measure is derived by assuming that all the people in a service area are served by the physicians located in that area. The simplest case is the small, approximately circular, single-physician area. If the population is randomly located within the area, the minimum expected distance to the physician is given by locating the physician in the center of the area. The appropriate model for this situation was developed by Eilon, Watson-Grady, and Christofides [20].

The problem becomes more difficult if the area contains more than one physician location, but, for most areas, use of a nearest-location algorithm produces a set of polygons with the physician centrally located in each polygon. The area of the individual polygon is estimated as the area of the service area divided by the number of physician locations. Although a precise result for expected distance to the physician is not possible, a lower bound is given by assuming circular subareas. Experimental procedures and a sensitivity analysis led to the selection of this procedure [21]. Thus the expected Cartesian distance to the physician in miles is given by

$$0.667(A/(\pi L))^{\frac{1}{2}}$$

where A is the area of the service area in square miles and L is the number of physician locations in the service area. Expected distance was estimated for each service area allowing for the different types of practice—solo, partnership, and group [22]. A conversion factor, estimated to be 1.3 [22], was employed to convert expected distance into expected road distance.

Lacking information specific to Indiana, we assumed a simple linear relationship between distance and demand rate. Using data obtained from a study by Kane [23], we estimated the slope of this line and assumed that the relationship observed for rural Kentucky would also hold for rural Indiana because of similar topography. This set of assumptions led to the following equation for geographic accessibility in a service area:

$$ACCESS_j = 100 - 2.5D_j$$

where $ACCESS_j$ is the geographic accessibility in service area j, expressed as a percentage, and D_j is the expected road distance to physicians in service area j. The interpretation of the accessibility calculations is that $100 - ACCESS_j$ is the percentage of potential demand that does not become expressed demand because of distance to a physician.

3. Compute the Effect of Economic Status on Expressed Demand. A portion of the potential demand for primary medical care is deflected by the monetary costs of obtaining care. The economic feasibility of obtaining care is defined on the basis of restricted activity days per year, using the data and procedures of Weiss and Greenlick [24]. As shown in Table 3, persons in low-income families need more medical care than persons in families with higher incomes. It is assumed (and this assumption is borne out by the data in Table 3) that the higher a family's income, the larger the percentage of needs (potential demand) expressed as visits to physicians. It is further assumed

Table 3. Computation of Economic Feasibility Index

Income category (dollars)	Physician visits/person/year* (1)	Percent primary care visits* (2)	Primary care physician visits (3) = (1) × (2)	Restricted activity days/person/year† (4)	Primary care contacts/100 restricted activity days (5) = 100/(4) × (3)	Economic feasibility (6) = (5)/PC15 × 100
Under 3 000 ...	6.2	54.3	3.4	33.7	9.99	37.1
3 000–4 999	5.1	56.4	2.9	20.7	13.9	51.6
5 000–6 999	4.6	59.2	2.7	15.3	17.8	66.1
7 000–7 999	4.8	57.6	2.8	12.8	21.5	80.1
10 000–14 999 ..	4.7	59.8	2.8	11.8	23.8	88.5
15 000 and over .	5.1	59.7	3.0	11.3	26.9 = PC15	100.0

* Source: *Physician Visits, Volume and Interval Since Last Visit, United States—1971* [15].
† Source: *Disability Days* [31].

that all the primary medical care needs of those persons whose family incomes are $15,000 or greater are expressed as demands for physician services—that is, economic feasibility is indexed as a function of their satisfied demand for services (see Table 3 for calculations).

The following logarithmic function is used to calculate the economic feasibility index for each service area:

$$FEAS_j = a \times \ln(I_j) + b$$

where *FEAS* is the index of economic feasibility (expressed as a percentage) for service area j, I_j is average family income in service area j, and a and b are constants to be estimated by regression analysis. The values of I used were the midpoints of the income categories except for the highest category, for which $15,000 was used. Using the data in Table 3, regression analysis yielded values of 0.274 and −1.68 for a and b, respectively, with an R^2 of 0.955.

The interpretation of these calculations is that $100 - FEAS_j$ is the portion of the potential demand in a service area that does not become expressed demand because of the monetary cost of primary health care.

4. Compute the Potential Demand. Potential demand is the need for primary health care as experienced by the population, disregarding factors that could interfere with satisfaction of that need [12,13]. This is the demand the population would place on the providers of primary care if the cost of obtaining such care, both monetary and nonmonetary, were zero and, of course, assuming that the population is uniformly able to recognize conditions for which medical care is appropriate.

Potential demand is considered here as a function of two characteristics of the population: age and need for care [15, 25–29]. The ideal population is assumed to have the same age distribution as the state of Indiana. The average utilization rate for the ideal population of Indiana ($\bar{V}_0$) was computed from NCHS data [15] as 2.87 visits/person/year. This is the base of comparison for the age factor. A utilization rate for each service area ($\bar{V}_j$) was computed as the population-weighted average of the utilization rates of the age groups. Those utilization rates ($\bar{V}_a$) have been estimated from Indiana and U.S. data [15,30] and are presented in Table 4. Using utilization rates by age in the calculation of the potential demand requires the assumption that values for *ACCESS* and *FEAS* are invariant across age groups and that the percentage of expressed demand that is satisfied is the same for each age group.

A similar procedure is used for family income. By assuming that restricted activity or bed days, as discussed previously here and in ref. 24, are proportional to the need for primary care services in a population, it is possible to estimate the need for primary care in a service area in relation to the ideal population. The mean number of restricted activity or bed days for a person whose family income is $15,000 or over is 11.3 days/person/year [31]. This variable, labeled $\bar{B}_0$, is the base of comparison for the income factor.

Table 4. Primary Care Utilization Rates by Patient Age Group

Age group (a)	Visits/person/year ($\overline{V}_a$)
Under 18	2.29
18–64	2.95
Over 64	4.00

The mean number of restricted activity or bed days for the population of the service area $\overline{B}_j$ is determined as the population-weighted average of restricted activity days over the income groups. The mean number of restricted activity days by income group is estimated from data in refs. 31 and 32 and presented in Table 5.

These calculations for age and family income are used to determine the potential demand in numbers of the ideal population in a given service area by the following equation:

$$V_{0j} = N_j \times (\overline{V}_j/\overline{V}_0) \times (\overline{B}_j/\overline{B}_0)$$

where V_{0j} is the potential demand in units of the ideal population for service area j and N_j is the actual population in service area j.

5. Determine the Expressed Demand. All of the potential demand, however, will not be expressed as visits to physicians. Factors that may impede some people from making visits to physicians must be taken into account [13]. Two such factors, geographic accessibility and economic feasibility, are taken into account in the model and are assumed to act independently of one another. Thus the expressed demand in a service area, V_j, is obtained by multiplying the potential demand in that area, V_{0j}, by the accessibility and economic feasibility factors for that area as computed in steps 2 and 3:

$$V_j = V_{0j} \times FEAS_j \times ACCESS_j$$

Table 5. Estimated Restricted Activity Days of Patients in Different Income Groups

Income category	Estimated restricted activity days/person/year*
Under poverty level†	30.9
Over poverty level and less than $15 000	14.6
$15 000 and over	11.3

* Estimated from data in *Disability Days* [31] and *Census of Population: 1970* [32].
† Source: *Census of Population: 1970* [32].

6. Compute the Availability Index. Availability is defined as the percentage of the expressed demand that is satisfied by the suppliers of primary care, that is, that becomes satisfied demand. The latter is defined as the amount of medical services actually given by the providers of primary health care in response to population demand [15, 33]. An availability index is constructed based on a model of the services that flow across the service area boundaries. The basic assumptions of this model are:

1. If the physicians have spare capacity after all the expressed demands of the individuals in the same service area are satisfied, this spare capacity is made available to the adjacent rural area.
2. If people in a defined service area can receive better service in the rural area, they will make demands on the primary care physicians located there.
3. Persons do not cross district boundaries in order to obtain primary medical care services.

The availability index is defined as the ratio of the supply of visits available in the service area to the expressed demand. The supply available is the initial supply plus (minus) the amount of supply transferred into (out of) the service area. The availability index for a service area ($AVAIL_j$) is computed by the following formula:

$$AVAIL_j = (MD_j \times P)/V_j$$

where MD is the number of FTPC physicians in area j, P is the capacity of one FTPC physician in terms of numbers of the ideal population, and V_j is expressed demand in service area j (the total number of physician visits for the year). An iterative procedure was developed to find the number of FTPC physicians in service area j using the three assumptions described above and was applied to each of the districts independently.

7. Compute the Primary Care Service Index. The primary care service index for a service area ($PCSI_j$) is defined as the ratio of the satisfied demand to the potential demand—that is, it is the product of the expressed demand and the availability index, divided by the potential demand, expressed as a percentage:

$$PCSI_j = (V_j \times AVAIL_j)/V_{0j}$$

This index is thus the percentage of the potential demand that is satisfied.

8. Compute the Physician Requirement and Need Factors. The physician requirement factor, XMD, is the number of additional FTPC physicians that would be required in order to satisfy the expressed demand that is not currently being met:

$$XMD_j = (V_j/P) - MD_j$$

where V_j is the expressed demand in service area j (the total number of physician visits per year for the area, in numbers of the ideal popu-

lation); MD_j is the total number of FTPC physicians in service area j; and P is the patient capacity of one FTPC physician in numbers of the ideal population. The physician requirement factor for each district is the sum of the requirement factors for the service areas in the district.

The need factor is the estimated average number of members of the ideal population who are beyond the capacity of each FTPC physician to serve but who would have to be served in order to satisfy that portion of the expressed demand that is not currently being satisfied. The need factor, XP_j, is expressed as follows:

$$XP_j = V_j/MD_j - P$$

The need factor for each district, XP_d, is

$$XP_d = (XMD_d \times P)/MD_d$$

where XMD_d is the number of additional FTPC physicians required to satisfy that portion of expressed demand that is not currently being met in district d and MD_d is the total number of FTPC physicians in district d.

Measures of Effectiveness of the Primary Medical Care System

Effectiveness indexes provide a measure of the capability of the primary care providers in each service area to meet the demand of the population of that area. To assess the performance of the primary medical care delivery system of a state, a policymaker needs statewide measures of effectiveness. Several measures of performance that can be derived from the indexes are discussed below.

Indexes Related to Minimum Levels of Service or Availability. Formulation of these measures of effectiveness is based on the assumption that the goal of the policymaker is that some minimum level of either the service index or availability index is obtained. The percentage of service areas that have index values below a defined minimum level is one such measure. Alternatively, a population-weighted average of index levels below the minimum level could be used.

Population-weighted Index for the State. This measure combines the indexes for the service areas by multiplying either the primary care service index or the availability index for a particular service area by the fraction of the state's population in that area and summing the products of all areas.

Physician Requirement Factor for the State. This measure is the number of additional FTPC physicians needed in the state to satisfy all of the expressed demand and is the sum of the requirement factors of the service areas.

The Analysis for Indiana

The procedure developed in this research is being used to evaluate the primary health care system of Indiana. It was first used in 1976 by the Board of Trustees of the Indiana Medical Distribution Loan Fund to identify areas in need of primary care physicians.

Table 6. Measures of Effectiveness of the Primary Medical Care System: Indiana, 1975

Measure	Value
Percent service areas with service index below 70%	43.9
Percent service areas with availability below 85%	30.8
Population-weighted service index (%)	69.6
Population-weighted availability index (%)	87.1
Statewide physician requirement factor	251

Data Sources for Physicians and Population

Data concerning primary care physicians in Indiana and their characteristics were obtained from the *Indiana Physician Profile* [7]. Data concerning the size and age distribution of Indiana's population were based on the *Indiana County Population Projections* [30]. The level of family income in each service area was derived from data in the 1970 United States Census [32].

Results for the State of Indiana

Table 6 summarizes the measures of effectiveness of the primary medical care system of Indiana. It shows that 43.9 percent of the service areas had a service index of less than 70 percent or that 43.9 percent of the service areas were meeting less than 70 percent of the potential demand. Furthermore, 30.8 percent of the service areas had physician availability indexes that were lower than 85 percent.

The population-weighted service index shows that less than 70

Table 7. Physician Requirement and Need Factors for Indiana Districts

District	Physician requirement factor	Need factor: ideal pop./ physician
1. Gary	38.0	348
2. South Bend	4.5	59
3. Fort Wayne	35.4	622
4. Lafayette	8.7	261
5. Anderson	32.7	415
6. Terre Haute	21.4	748
7. Indianapolis	44.1	291
8. Richmond	6.6	226
9. Bloomington	3.3	97
10. Lawrenceburg	13.4	989
11. Evansville	28.9	610
12. New Albany	14.3	521

Table 8. Service Areas with Need Factors Greater than 900

Service area	Accessibility index	Economic feasibility index	Availability index	Primary care service index	Physician req. factor	Need factor
Lawrenceburg-rural	77	79	37	22	11.8	4 418
Fort Wayne—rural	83	84	44	31	17.6	3 302
Bluffton	91	84	44	33	2.9	3 302
Angola	92	79	46	34	2.3	3 060
New Albany—rural	79	78	49	30	10.1	2 753
Terre Haute—rural	80	80	52	33	11.3	2 428
Loogootee	89	79	54	38	1.0	2 291
Evansville-rural	77	80	54	33	12.7	2 291
Huntington	94	84	62	49	3.6	1 595
Mt. Vernon	93	79	63	46	1.3	1 527
Bloomfield	92	80	52	33	11.3	1 473
Gary-rural	84	80	66	45	9.2	1 379
Knightstown	89	81	67	48	0.8	1 320
Richmond-rural	81	81	67	44	5.8	1 320
Anderson-rural	83	83	68	47	9.8	1 215
Spencer	92	77	71	50	0.7	1 099
Linton	93	78	72	52	1.6	1 029

percent of the potential demand can be satisfied. The population-weighted availability index shows that 87 percent of expressed demand is satisfied. The value of the statewide physician requirement factor is 251, which shows that an additional 251 FTPC physicians are needed in order to meet the 13 percent of the expressed demand that is not satisfied. Since a full-time physician by definition provides the most visits per year of any physician, the requirement factor may be viewed as the minimum number of additional physicians required.

Results for Indiana Districts

The requirement factors and need factors for each of the 12 Indiana districts are presented in Table 7. The need factor reflects both primary care availability and the extra work each physician has to perform if he or she is to satisfy all of the expressed demand. Table 7 shows that 8 of the 12 districts have need factors of 10 percent or more of the capacity of an FTPC phyiscian (2,700) and four districts have need factors of 20 percent or more of this value. These results indicate that the demand for care placed on primary care physicians in districts in various parts of Indiana significantly exceeds their capacity for providing such care.

Table 9. Cumulative Distribution of Service Area Need Factors by Percent of the Equivalent FTPC Capacity

Range (percent of 2,700)	Number of service areas	Percent of service areas
All	91	100.0
0	40	44.0
0–10	15	16.5
10–20	11	12.1
20–30	8	8.8
40–60	9	9.9
70–80	0	0.0
90–100	3	3.3
100–170	5	5.5

Results for Service Areas

Values for the geographic accessibility index, the economic feasibility index, the availability index, the primary care service index, the physician requirement factor, and the need factor were compiled for each service area. Table 8 (p. 301) shows those 17 areas with need factors greater than 900, which is one-third of the capacity of one FTPC physician.

Finally the distribution of the service area need factors in terms of percentages of the FTPC physician capacity (2,700) is shown in Table 9. The table shows that in order to meet all of the expressed demand in the state of Indiana, each physician in 36 of the service areas would have to carry a patient load at least 10 percent higher than his or her estimated maximum. In 17 of the service areas, each physician would have to care for at least 40 percent more patients than his or her maximum. Table 8 shows that an additional number of physicians equivalent to 114 FTPC physicians is required to meet the expressed demand in these 17 service areas. On the other hand, 40 service areas were found to have no need of additional primary care physicians.

Application of Results in Indiana

Beginning in April 1976, this research has been used to assist the members of the Board of Trustees of the Indiana Medical Distribution Loan Fund to determine the areas in Indiana in greatest need of additional primary care physicians. The fund is a loan-forgiveness program that supports medical students who agree, in exchange, to practice primary medical care in an area of need. Students funded by this program receive a list of the areas in Indiana in greatest need of additional primary care physicians, and medical graduates select practice locations jointly with the loan fund board of trustees. Indiana has about 300 medical graduates per year, and 95 students have participated in this program to date. Sixty-four of these are in postgraduate training and five are practicing physicians. The remaining 26 are still in medical school. It is hoped that this research will continue

in helping to rectify the maldistribution of primary care physicians in Indiana.

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