Research Notes

Variation in the Character and Use of Chicago Area Hospitals

by Richard L. Morrill and Robert Earickson

This report summarizes briefly three of the analyses of variations made by the Chicago Regional Hospital Study in order to reduce a large number of demographic and ecologic variables to a small number of controlling variables. The correlations determined are intended to be used in the construction of a descriptive simulation model, from which can be generated a predictive model and, eventually, a prescriptive model capable of testing alternative future plans for the hospitals of the region.

Some outside observers of the health system are tempted to view hospitals as offering a homogeneous service, patients as having common needs, and the "hospitals problem" as one of the ratio of capacity to demand. Those who are called upon to evaluate in detail the hospital needs of a specific area, however, know that hospitals are not alike, nor are their patients. The Chicago Regional Hospital Study [1], which aims to provide criteria for evaluation of existing hospital systems and future needs, realized that a first step must be an understanding of the significant variations among hospitals and among their patients that affect their location and use. In a metropolis like Chicago, the more than one hundred hospitals vary greatly in size, specialization, control, religious affiliation, and location; and populations in turn vary in their preference for hospitals of different kinds, their ability to pay, and their location with respect to hospitals.

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Three studies are briefly reported here:

1. Estimation of the hierarchy of hospital services—that is, the level of service offered.
2. General classification or grouping of hospitals based on hospital characteristics, service areas, and relative location.
3. Prediction of the use of general hospitals through regression analysis of flows between communities and hospitals.

The first study reveals significant distinctions in the level of service offered; facilities and services, kinds of residence and intern programs, size of medical staff, and overall size are the major differentiating characteristics. The second undertakes a principal-components analysis, in which many variables involving hospitals and their patients are reduced to a few major dimensions of variation and hospital groups are then classified on the basis of these dimensions. Groups reflect especially variation in volume of service offered, relative location of hospitals and patients, and scope of service. The third study focuses on a sample of patient flows between specific communities and hospitals. A few variables involving the characteristics of communities and hospitals and the relationships between them were able to account for about two-thirds of the variation in the pattern of flows. A form of intervening-opportunity interactance model proved to be the best predictor.

HIERARCHY OF HOSPITAL SERVICES

Hospital services do not constitute a homogeneous output. Some hospitals, typically the smaller ones, have a limited range of facilities and perform a smaller range of services. A few hospitals, usually large, have highly specialized diagnostic and treatment facilities and personnel and are able to handle unusual and difficult cases. Hospitals of the latter type in fact have a partially different output; they provide a higher level of service, in addition to the more usual services. Their patients are likely to come from greater distances, partly because hospitals closer to home may be unable to provide these services. A more complex output is, of course, one explanation for apparent diseconomies of scale—that is, higher average costs per patient with increasing size. Returns to scale probably obtain for hospitals within a similar group.

The level of service of a hospital is a simple function of the presence or absence of various specializations. Schneider [2], in a study of Cincinnati hospitals, suggested a three-level hierarchy: the few very large hospitals had a virtual monopoly of Type A services (dermatology, plastic surgery, psychiatry, neurology, thoracic surgery); and large and medium-size hospitals shared a second level of specialties, absent in smaller hospitals. (It should, of course, be borne in mind that even the small hospital is itself at a fairly high level in the entire health system.) In the absence of data on specializations, the level of service can be estimated from the facilities. The facilities available are listed (though with little regard to quality or quantity) by the

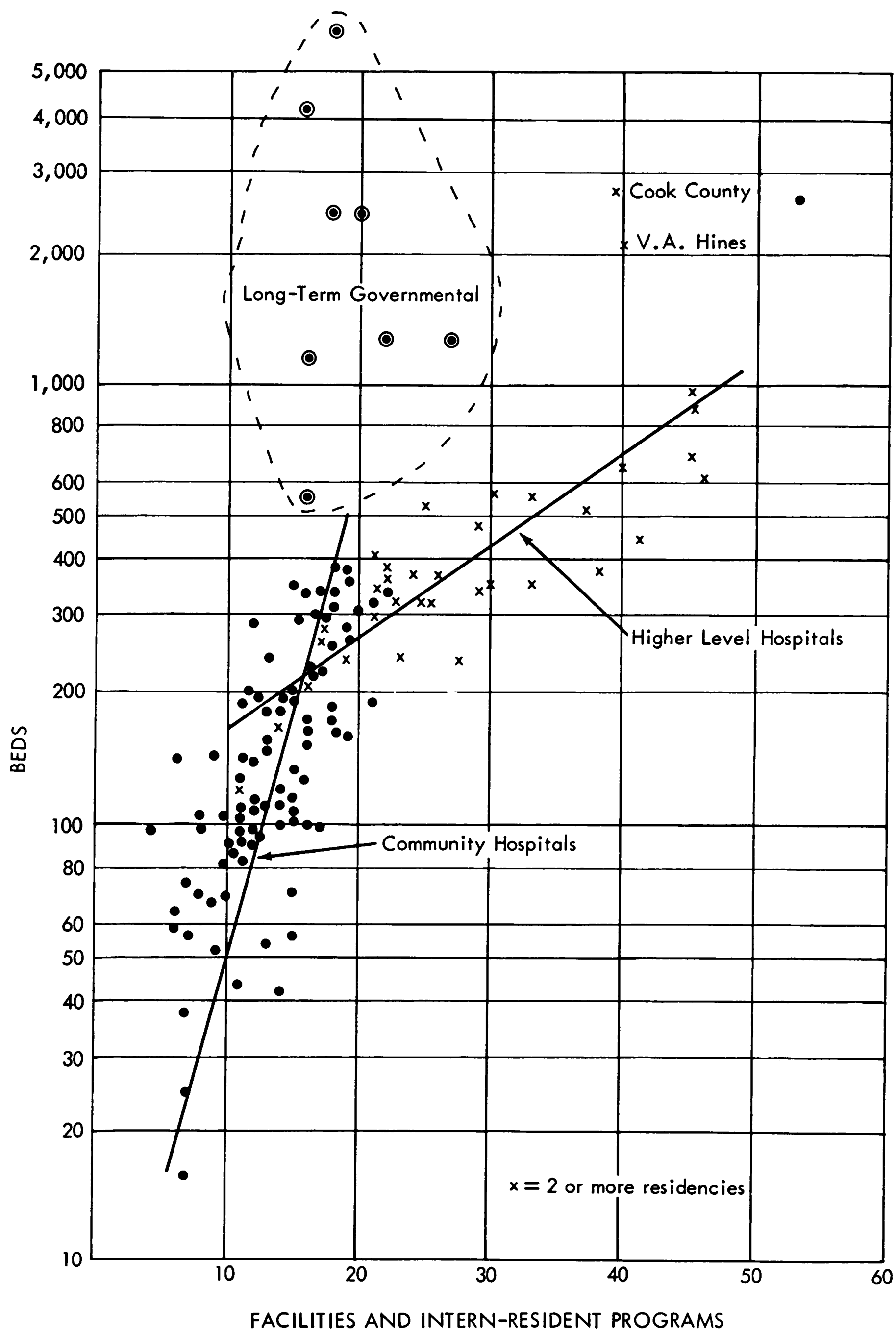


Fig. 1. Hospital size, facilities, and programs.

American Hospital Association in the Guide Issue of its journal, *Hospitals* [3]. The number of residencies and internships, by hospital and by specialty, and the number of paramedical staff members of hospitals are also available [3,4].

Figure 1 graphically portrays the relation between number of beds and an "index" of specialization—actually the sum of the number of facilities and the number of specialties with interns and/or residents. The long-term governmental institutions are set apart, since they are less concerned with care of acute illness and therefore have many beds but few services or facilities. The large university hospitals are also set apart, as they contain typically both more beds and many more services and facilities. The very small hospitals (with a few exceptions) have a minimum number of services.

Correlations between Hospital Size and Services

The relation between bed complement, facilities, and number of intern or resident specialties was subjected to regression analysis. Table 1 indicates the fairly strong positive relation between size and scope. From these correlations it can be concluded that Figure 1 describes not one relation but two fairly strong ones. For the hospitals with a higher level of services, the number of intern and resident programs increases fairly rapidly with size, after a threshold size of about 200 beds. This emerges clearly when predicted values are computed from the regressions (Table 2). The general relation between size

Table 1. Coefficients of Correlation between Hospital Size and Services

	All hospitals	Higher level*	Community
Facilities and services	.77	.76 (.82)	.73
Facilities only	.82	.63 (.95)	.73
Intern/resident programs	..	.72 (.87)	..

*Figures in parentheses are values obtained when governmental hospitals were excluded.

Table 2. Predicted Values for Services and Facilities Computed from Regression

Facilities and services	Bed complement						
	50	100	200	500	1000	*B**	*r*
Higher level hospitals:							
Intern/resident programs	..	..	0	12	21	31.2	.87
Facilities, services, and intern/resident programs	..	0	14	33	47	47.4†	.95
Community and district hospitals: facilities and services	10	12+	15	19	..	9.1†	.73
All hospitals: facilities, etc.	6	13	18	26	33	20.66	.80

*B = amount of change in facilities, etc., per 1.0 change in log of bed complement, as from 10 to 100, 50 to 500.

†These regression lines are shown in Figure 1.

and scope may also be seen from Table 3, based on American Hospital Association listings, which groups the hospitals of various sizes according to levels of service. It may be observed that the large majority of hospitals are intermediate in size and service.

Hierarchical Classification

On the basis of these data, a more complete classification is suggested in Table 4. The hospitals of Group A in this classification are uniformly large, possess the widest range of facilities (particularly specialty programs for interns and residents), and have the largest professional staffs. They are all affiliated with medical schools. With two exceptions, these hospitals are all central in location. All the Group B hospitals have some medical school relationship and have moderately large medical staffs. The majority of this group are rather close to the city center, but a few major suburban hospitals are included. These provide an intermediate level of service, not too far from home, for many patients. Group C, the largest group, consists of the many moderate-size community hospitals. They are the most widely and evenly spaced. They may be considered the norm, equipped to handle most normal

Table 3. Number of Hospitals at Various Service Levels, by Size*

Number of facilities & services	Bed complement: Under 100	100–399	400 and over
12	26	6	0
12–24	6	80	1
25 and over	0	6	13

*Data from American Hospital Association listings.

Table 4. Summary of Hospital Hierarchy and Classification

Classification	No. of hospitals	Mean no. of beds	Mean no. facilities	Mean no. intern/resident programs	Mean no. total services	Mean no. medical staff
Group A: Teaching and research hospitals	10	995	24	17	41	180
Group B: Regional and district hospitals, intermed. service level	24	360	20	5	25	30
Group C: Community hospitals	67	205	15	0	15	3.3
Group D: Very small hospitals	24	64	10	0	10	1
Group S: Long-term institutions	25	800	16	1	17	12
All hospitals	150	362	16	2	17	19
Groups A,B,C,D	125	270	16+	2	18	22

needs and situated fairly close to most patients. But since they have extremely small house staffs and few approved intern or resident programs, they do not meet the theoretically desired standards for the modern hospital. Group D, arbitrarily defined as those hospitals with fewer than 100 beds, is less typical. Here we may distinguish between those community hospitals whose size is restricted by their location in less-populated, semirural areas and the small, perhaps hospitals, perhaps restricted to a special purpose within Chicago proper (for example, Negro hospitals).

Subject to the validity of the assumption of normality, some statistical tests of the significance of the classification in Table 4 were carried out. Differences in the means of Groups A, B, C, and D in beds, facilities and services, intern and resident programs, and medical staff are all significant at the 95 percent level (except, obviously, interns and residents for Groups C and D, both 0).

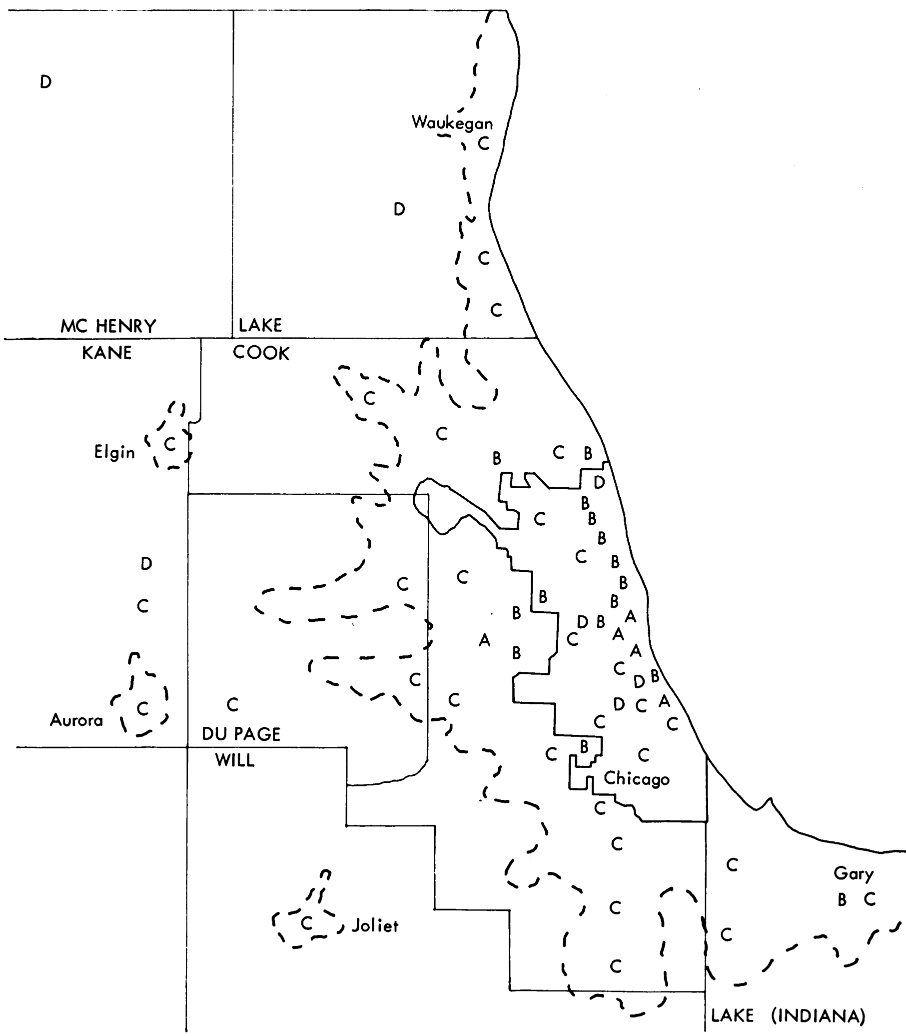
When hospitals in these groups are mapped (Fig. 2, next page), one can observe the concentration of the higher-level hospitals near downtown Chicago or in older, larger satellite cities or suburbs. Whether this degree of concentration is necessary or desirable is difficult to say. However, if only about 10 percent of patients, even in a large hospital, require more specialized services, then the threshold population for entry for such specialized services must be on the order of 500 000 to 1 000 000 people. Considered in this context, the present pattern is not surprising. Hospitals with high service levels are located close to centers of transport and population, where they can share a regional market. These hospitals have a wider drawing power and their patients travel a longer mean distance. Also as would be expected, they have less definable service areas. Whereas community hospitals tend to separate and seek a somewhat protected trade area, higher-level hospitals cluster together so that their service areas cover much of the metropolitan area. All but 6 of the 34 Group A and Group B hospitals are part of clusters, but only 27 of 67 Group C hospitals are in clusters, and 10 of the 27 are shared-market hospitals in satellite cities, themselves isolated from competition.

PRINCIPAL-COMPONENTS ANALYSIS OF VARIATIONS

Hospitals vary in many ways; they may be arrayed according to other factors than size and facilities. For example, hospitals differ in their willingness to accept Negro patients and in the domination (proportion of an area's patients attracted to the hospital) that they exert over nearby communities.

There may be relatively few, if any, really independent dimensions of variation. Data were collected for 123 of the Chicago area's hospitals on 99 variables concerned with patient capacity, quality and service, costs and means of payment, patient population, hospital service area, relation to other hospitals, change over time, and occupancy and length of stay. Factor analysis, appropriate for problems in which there are many interrelated variables, yielded one possible set of variations, emphasizing the relation of hospital and patient rather than the internal operation of the hospitals.

The principal-components method, analyzing the degree of correlation among variables, was used to reduce variations among the 99 variables to nine major components or independent dimensions of variation, each representing a set of related variables. The hospital scores or values on the nine component dimensions—that is, composite variables—were then used for a grouping analysis. This resulted in a classification of hospitals with high similarity within groups but significant differentiation between groups.



A—Teaching and research
B—Intermediate level
C—Community hospitals > 100 beds
D—Community hospitals < 100 beds
Broken line indicates limit of urbanized area

Fig. 2. Functional hierarchy or levels of care in Chicago area hospitals.

Principal Components

These nine significant dimensions accounted for two-thirds of the variance among all 99 variables. Highly correlated variables reduced to fewer composite variables. The remaining variance is accounted for by peculiarities of individual hospitals or by relations involving few variables and hospitals. Since the dimensions are composite, they cannot be precisely defined, but the following descriptions reflect the variables comprised.

1. This dimension arrays hospitals by *amount or volume of service*, especially medical-surgical. Highly represented variables include those measuring number of admissions, patient days, expenses, payroll, and personnel, all of which were highly correlated. This dimension accounted for 26 percent of the explained variance in the battery of variables. Such a ranking, essentially by number of admissions, is of course the most obvious form of variation. Personnel and payroll are much better predictors of capacity than number of beds, according to this result.
2. This dimension (accounting for 15 percent of explained variation) is spatial, ranking hospitals by the *character of the service area and the relative location* of the hospital. Highly represented variables include the proportion of a hospital's patients (medical-surgical or obstetric) coming from its own community and its own hospital district and the distance of the hospital from the Loop (city center). All these variables had been highly correlated. High-ranking hospitals on this dimension are those whose patients are concentrated locally and which tend to monopolize care in their communities—most typically, hospitals in widely separated satellite cities or distant suburbs. Since population density declines outward from the city center, service areas on the outskirts are also likely to be higher-ranking on this dimension. At the low end of the ranking are special-purpose hospitals and large teaching hospitals, which attract patients from the entire metropolis but do not dominate their local area.
3. A dimension (accounting for 13 percent of variation) that arrays hospitals according to *length of stay and quality or scope of service*. Highly represented variables include length of stay (for various groups), facilities and services of hospitals, intern and resident programs, expenses per admission, and type of ownership or control. This dimension reflects the longer stay and greater expense associated with patients requiring more specialized kinds of treatment. Highest-ranking hospitals are the Veterans Administration hospitals, then the major teaching and research hospitals. The typical low-ranking hospital is small, often private, and has many Negro patients.
4. This dimension (accounting for 12 percent of variation) orders hospitals by the *importance of obstetric and pediatric care*. Represented variables, all correlated, include obstetric and pediatric beds, admissions, patient days, and occupancy rates. This dimension indicates that hospitals tend to reflect, in their patient emphasis, the demographic characteristics of

the communities around them. This and the preceding dimension illustrate distinct forms of variation: an increase in overall capacity does not necessarily mean an increase in quality or importance of obstetric care.

5. The fifth dimension (8 percent of variation) arrays hospitals according to their *recent dynamism*, ranging from newer, growing hospitals to older, stagnant ones. Represented variables are those which measure changes in beds, admissions, or patient days and population in the periods 1950–60 and 1960–65, as well as age of hospital. In general, the most dynamic are newer suburban hospitals; the least, older institutions in the city, especially public hospitals in areas of stagnant population. The dimension is significant because of patients' apparent preference for newer hospitals.
6. A dimension (8 percent of variation), also spatial, that ranks hospitals according to their *competitive position.* Highly represented variables include distance to the nearest and next nearest hospitals, community population, and proportion of the community's patients visiting local hospitals. High-ranking hospitals are those in highly competitive clusters in large close-in communities; low-ranking hospitals are quite isolated ones.
7. This dimension (7 percent of variation) orders hospitals by their *propensity to admit nonwhite patients.* Represented variables are those that reflect Negro community conditions (lower income, lower average age) and the proportion of Negro admissions. This dimension is important because the Negro community does not have free access to the hospital system.
8. This dimension (6 percent of variation) distinguishes between hospitals with high *personnel and expenses per bed and proportions of patients on public aid* (Veterans Administration and county hospitals) and the proprietary (for-profit) type, which reduce costs to a minimum and rely on full ability to pay.
9. Dimension 9 (5 percent of variation) orders hospitals by the *importance of elderly patients.* Again, the dimension indicates that the hospitals tend to reflect the age distribution of the population.

These results are complementary to those of Rosenthal [5], who used principal components in an analysis, for states rather than hospitals, of the ways the using population varies and the relative importance to hospitals of various classes of the population.

Grouping of Hospitals

The above nine dimensions are new or composite variables that can substitute for most of the original 99. Grouping analysis finds those hospitals which are most similar in their scores or values in terms of these new variables. The method is sequential. The two hospitals that have the smallest differences in scores are found, then the next pair, and so on. Gradually all hospitals are added to a group, with progressively weaker links, until all are grouped. The significance of groups is found by comparing the variation within them with that between groups. Since the dimensions involve both internal characteristics of hospitals and external characteristics of their service areas, this grouping is more complex than the classification by size and scope of services alone.

Ten groups and eight "isolates" were identified. The largest group brought together hospitals that occupied middle positions on most dimensions and thus might be considered typical. Most of the other groups and isolates, then, represent extreme positions on various dimensions (Figures 3 and 4).

The largest group of most typical hospitals, designated "medium city," includes most medium-to-large city and inner suburban hospitals with small-to-moderate staffs, good facilities, and a few interns and residents. They are characterized by competitive overlapping service areas. Although they rank intermediate on most dimensions, they are rather low on dimensions 2 (compactness of service areas) and 7 (nonwhite) and high on 6 (competitive position). A particularly close core group contains mostly older hospitals; peripheral subgroups include a few city hospitals of moderately high level (that is, more interns and residents), special-clientele hospitals, and a few newer hospitals in the city.

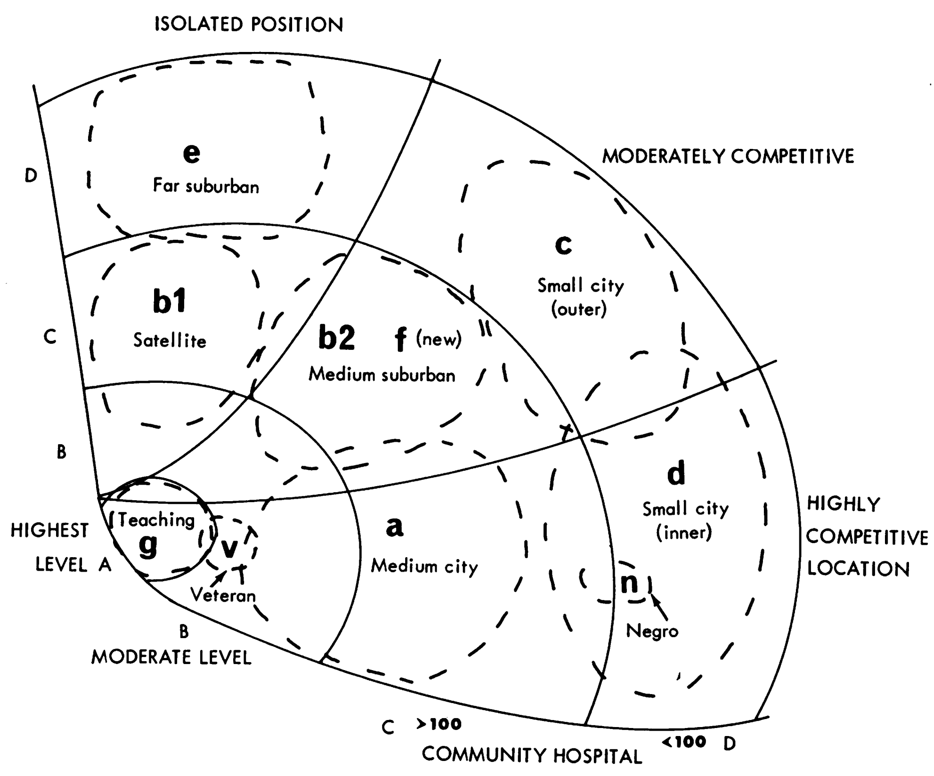
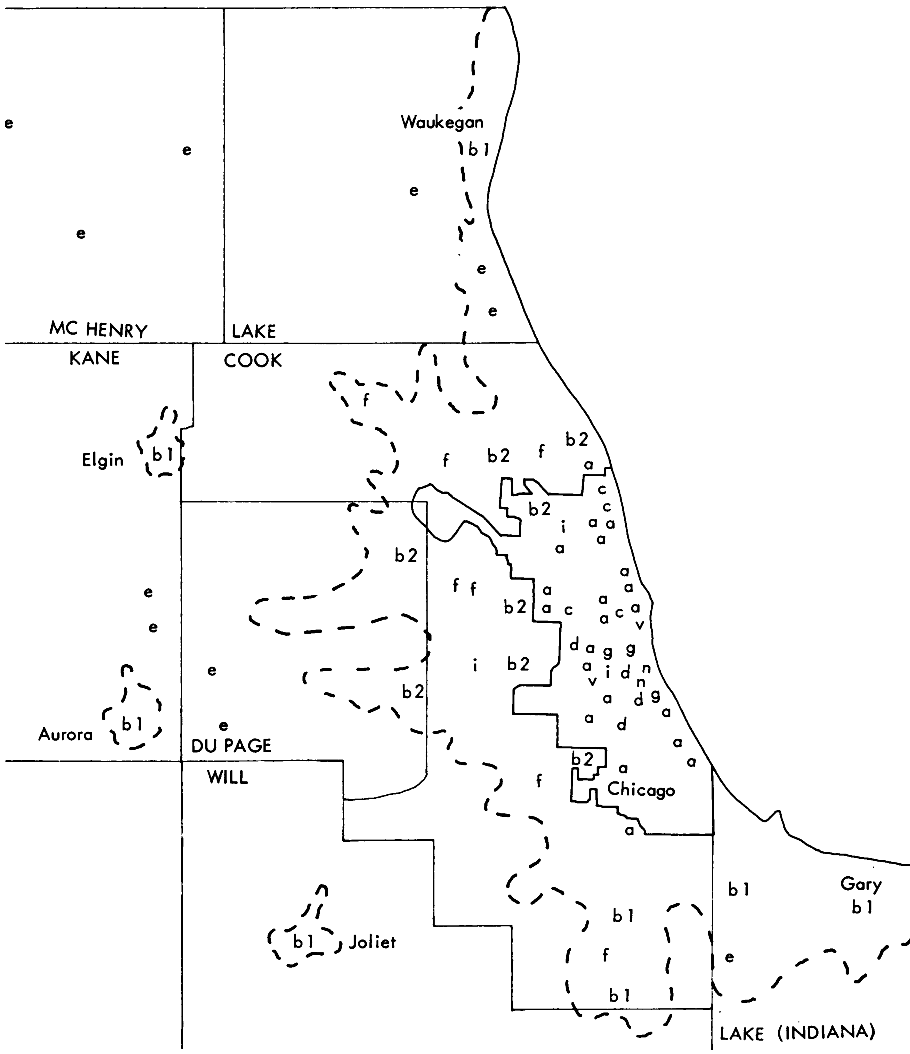


Fig. 3. Graphic summary of hospital grouping in relation to hierarchical level of services.

Satellite city hospitals with strongly dominated service areas form a distinct group ($b1$). They are of medium size and are located in small isolated clusters. They rank very high on dimension 2 (compactness of service areas). A related set ($b2$), "medium suburban," includes most medium-to-large suburban hos-



a—Medium, competitive
b1—Satellite
b2—Medium suburban
c—Small, outer city
d—Small, inner city
e—Small, far suburban
f—New suburban
g—Teaching and research
i—Isolates
n—Negro
v—Veteran

Broken line indicates limit of urbanized area

Fig. 4. Grouping of Chicago area hospitals.

pitals, located in large, closer suburbs, with fairly strong service areas yet some competitive overlap. Another related group (f), "new suburban" hospitals, includes similar hospitals, which would have been part of the $b2$ group but for their unusually high position on dimension 5 (newness).

Small city hospitals (c and d) are community hospitals of limited capacity and scope of service (low positions on dimensions 1 and 3). The c set comprises hospitals mainly in outer city areas, with fewer Negro patients; the d set, hospitals that are more central and southern in location and accept more nonwhite patients. Small far suburban hospitals (e) also have a limited scope of service but are distinguished from c and d by their far stronger domination of their communities (high position on dimension 2).

The six very large teaching and research hospitals associated with medical schools form a separate group (g), owing to extreme rank on dimensions 1 (size) and 3 (scope). The two city Veterans Administration hospitals form a small group, as do two small close-in hospitals with largely Negro patients.

Finally, there remain eight hospitals with patterns so unlike the other groups and one another that they must be considered isolates. Included are Cook County Hospital, a suburban Veterans Administration hospital, and Children's Hospital.

REGRESSION ANALYSIS OF COMMUNITIES-TO-HOSPITAL FLOWS

The grouping of hospitals according to the principal dimensions of variation provides a summary statement of the degree of complexity in hospital and patient characteristics that must be taken into account in any realistic evaluation of the present system. In the dense Chicago core, patient differences in race, ability to pay, age, veteran status, religion, and other characteristics are reflected in similar hospital differentiation, and the sheer mass of demand justifies specialization of purpose and division by level of service. In low-density far suburban areas, where much less differentiation is possible, the problem is simplified.

The preceding analyses identified the significant variations among hospitals and patients. The utility of the endeavor can be tested by attempting to predict or account for the actual patterns of patient-hospital flow; that is, given a few characteristics of hospitals and community populations, can the flows between them be explained? Many studies of demand for aggregates of hospital services by aggregates of population have been made [6,7]. This analysis, in an amplification of an earlier Chicago study [8], attempts a rather fine spatial disaggregation, estimating the demand for particular hospitals on the part of individual fairly small communities.

A discharge survey showed that for the medical-surgical services of 123 hospitals and 206 communities in the area, less than 8000 of the 25 000 possible flow paths were actually taken in the survey period of February 1965. Of these, 1100 flows were randomly selected as a one-eighth sample in the hope of explaining the pattern. Another sample of 450 flows of obstetric patients (also one-eighth) was chosen. Since even the discharge survey yielded but a tiny volume for a large number of flows, sampling error is often great (indeed, actual use of such paths is probably highly variable), hence one cannot expect really high levels of explanation. The levels reached, $r = .8$, $r^2 = .65$, are surprisingly good, given the nature of the data and the known factors that could not be included.

For both medical-surgical and obstetric flows, three dependent variables used in an earlier Chicago study of patient travel to hospitals [9] were tested: (1) the absolute number of patients coming from a community to a hospital; (2) the proportion of all the patients of the hospital accounted for by that flow; and (3) the proportion of all the patients of the community accounted for by that same flow.

Of some 18 variables tested, the following proved most significant:

Total population of the community
Population 65 years and older
Females aged 15–44 (for obstetric care)
Hospital beds
Physicians referring patients to the hospital
Facilities in the hospital
Index of similarity of community and hospital
Intervening population closer to hospital than the sending community
Intervening beds closer to the community than the receiving hospital

Income or educational levels as such added little explanation. The number of competing beds in a cluster with the hospital and the distance between community and hospital were very significant if the intervening-opportunity variables were omitted, but they were less successful in reducing total variance. Variables concerning source of payment are known from other studies [10] to be important but could not be meaningfully incorporated into this statistical model. Above all, the fact that the physician intervenes between patient and hospital is of basic importance [11], but this too could not be employed in the analysis without risk of circularity. For this reason also, number of beds rather than of admissions was used to measure size, although the latter would have improved results.

The index of similarity is a simple scale: 0 signifies that the hospital and community were unlike—for example, a heavily Catholic community with a Protestant hospital; 1, that the community was moderately represented in the religious or racial affiliation of the hospital; and 2, that the community was predominantly of the same character.

Best results were obtained when log transformation was performed on all variables. Hence, given the significant variables, a rather classic intervening-opportunities interactance model proved a surprisingly good predictor.

Most deviations with respect to the smaller flows can be attributed to sampling uncertainty. Underestimation of many large flows and overestimation of many moderate flows seem a result of the omission of the physician role, and to a lesser extent of source-of-payment variation. Physicians have affiliations with but one or very few hospitals and refer all their patients there, irrespective of alternate intervening opportunities. Underestimation of movements to centrally located hospitals was common, because the analysis did not allow for the fact that many patients come to downtown physicians and are referred to nearby hospitals.

Although there is variation among tested models, the relative importance of variables in explaining variance is typically as follows:

40 percent: Population and/or hospital size and scope
40 percent: Intervening beds and/or population
10 percent: Religious or racial correspondence
10 percent: Quality of hospital

The flows between communities and hospitals, whether absolute or proportional from the hospital or community viewpoint, are approximately equally influenced by size of demand and opportunities and by amount of intervening demand and opportunities, but the flow is modified upward if the communities and hospitals are similar, downward if they are not. Increasing quality reduces the volume of flow, since hospitals offering a higher level of service handle smaller numbers of more difficult cases from a wide area.

Model 1 ($r = .807$, $r^2 = .651$)—Medical-surgical cases:

$$\text{MS cases} = \frac{(15.8\ \text{Pop.}^{.423})(\text{Beds}^{.507})(\text{Similarity}^{.367})(\text{Pop. } 65{+}^{1.238})(\text{MDs}^{.203})}{(\text{Interv. Pop.}^{.425})(\text{Interv. Beds}^{.298})(\text{Facilities}^{.42})}$$

Model 2 ($r = .810$, $r^2 = .656$)—Percent of hospital's medical-surgical patients from community:

$$\%\ \text{Hosp.} = \frac{(131.2\ \text{Pop.}^{.291})(\text{Interns}^{.104})(\text{Pop. } 65{+}^{.142})(\text{Similarity}^{.197})}{(\text{Interv. Pop.}^{.307})(\text{Interv. Beds}^{.277})(\text{Facilities}^{.436})}$$

It can be seen that from the hospital point of view, community characteristics are most important.

Model 3 ($r = .785$, $r^2 = .616$)—Percent of community's medical-surgical patients to hospital:

$$\%\ \text{Comm.} = \frac{(108.7\ \text{Beds}^{.343})(\text{Physicians}^{.209})(\text{Similarity}^{.249})}{(\text{Interv. Beds}^{.276})(\text{Interv. Pop.}^{.320})(\text{Facilities}^{.242})(\text{Pop.}^{.215})}$$

In contrast to Model 2, the direct relations have only hospital, not community, characteristics. Population of the community becomes an inverse relation, since the larger the community the greater the number of hospitals visited and the less dominant any one.

Model 4 ($r = .77$, $r^2 = .604$)—Obstetric cases: Except for level, this does not differ significantly from Model 1.

Model 5 ($r = .775$, $r^2 = .601$)—Percent of hospital's obstetric cases from community: This model is likewise similar to Model 2, except that interns and population over 65 are not significant variables.

Model 6 ($r = .785$, $r^2 = .616$)—Percent of community's obstetric cases to hospital: Similar to Model 3, except that income appears as a minor factor increasing flows.

These simple models, with but seven or eight variables concerning hospital and community and a measure of the "social distance" between them, are able to account for a reasonably high proportion of variance in flows. These results certainly corroborate the findings of the first two analyses of variability, although the full scope of that variability could not be handled in these predictive models.

SUMMARY

These analyses describe the complexity of the Chicago hospital system and provide a reasonable explanation of the pattern of use of that system. With respect to the eventual goal of evaluating the adequacy of the system, the studies provide the variables that must be taken into account and the relationships among characteristics of hospitals and populations; these in turn suggest the goals sought by patients and hospitals and the restraints in the present system that hinder the fulfillment of these goals.

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