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A location-based comparison of health care services in four U.S. states with efficiency and equity

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ABSTRACT

This paper examines the efficiency and equality in geographic accessibility provided by hospitals. We use the criteria efficiency, availability of the service, and equality. Quantitative measures are defined for all criteria, and are measured using a geographical information system. We then compare existing locations with optimal locations satisfying two objectives, one that minimizes hospital–patient distance, and another that captures as many patients as possible within a pre-specified time or distance. The results of our study indicate that the existing locations provide near-optimal geographic access to health care. Some potential for improvement is indicated.

1. Introduction

Even if it appears that only recent debates have put health care problems on the (political) agenda, health-related issues have long been the focus of much research. Factors such as the scarcity of recourses (in conjunction with increased expectations), increasing costs of medical personnel and sophisticated equipment, and an ageing population that requires more health care services have brought the topic to the front of the agenda of politicians and practitioners alike.

Considering the aforementioned factors, increased efficiency of available resources is called for. Criteria that are used by the planners as well as the general public to evaluate expenditures will be the quality of services (a somewhat nebulous concept that needs to be quantified and measured by an appropriate proxy), the accessibility of services, and possibly the fairness of the services. The quality of medical services could be expressed in terms of expected or worst case waiting times for a specific service, the expected success rates of necessary procedures, or others. The accessibility of services is probably easier to measure in terms of distance to a potential patient's home, or the expected coverage of the population at large within a given amount of time. Fairness, another soft concept, could be expressed as the variance of quality and availability of medical services in different regions.

There are many tools to achieve the criteria outlined above. Choice of the size of a facility, the location of a facility, the services offered at a hospital or health post, the hierarchies and referral systems used in the process, incentives to do preventive work, different triage systems, nurses and doctors' schedules can and will all influence the quality and availability of medical services.

This paper investigates one specific aspect of health care management, *viz.*, the effects of the location of hospitals on the geographic accessibility of health care. Locating hospitals is a process that must take into consideration many different stakeholders: patients who need ready access to the facility, doctors who want attractive and easy-to-reach workplaces, taxpayers who want value for their dollars, and politicians who want to demonstrate their ability to deliver a quality product. This paper will investigate some of the measures that determine the geographic access of health care. More specifically, it will provide some guidance to policy makers regarding the potential for improvement regarding the locations of the hospitals with respect to a number of criteria relevant in the context.

Many of the studies that deal with hospitals focus either on the correlation between accessibility of the hospital to the population at large and the health of said population, or on the accessibility of hospital care for certain groups. One of the early studies that evaluates the efficiency of hospitals is [27]. In their paper, the authors develop a simulation model to evaluate the efficiency of hospital locations in the Chicago metropolitan area. This paper is one of the earliest to have customers travel on a network from their own location to physicians and hospitals. The authors' model also

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includes patients' religious and racial choices for the facility they patronize. Because of the technology at the time, the paper's modeling of the network and patient location is somewhat coarse, but they highlight the idea that going to the nearest facility is not always optimal or even feasible due to the type of services needed or racial or religious considerations.

There is a significant number of studies concerning the accessibility of health care facilities. Newhouse et al. [33] measured accessibility as the number of specialists per capita. Rosenthal et al. [35] modeled customer and physicians' locations on a zip code level and modeled accessibility as the number of physicians per capita and the average distance between patients and physicians for rural and urban areas. Using more detail, Love and Lindquist [23] assessed customer and hospital locations at the census block group level for the State of Illinois.

Hare and Barcus [19] followed a different line of research. Their accessibility measure is ultimately the expected time between a customer (approximated by zip code) and the nearest hospital. The road distances and speeds are then used to estimate the travel time. The authors' main results are the correlation with areas of low accessibility of hospitals and (rural) areas of poverty.

Concerning the correlation between accessibility and preventative care, Currie and Reagan [8] find that among inner-city children, each additional mile to the closest hospital (which is used by many in this population group not for emergencies but for routine medical checkups) corresponds to a 3% decrease in the probability that a child has had a medical checkup.[1]

Goodman et al. [40] achieved a similar result in their study. In particular, they determined that patient–hospital distance is inversely correlated to the likelihood that patients will seek care in discretionary services. Similarly, Nattinger et al.'s [31] study revealed that longer patient–hospital distances correlated with lower use of follow-up radiation treatment after a lumpectomy. Finally, Buchmueller et al. [4] used a quasi-experimental approach, using actual hospital closures' affects on accessibility on patient outcomes. They find that patient–hospital distances positively correlate with deaths due to heart attacks and accidental injuries.

After briefly discussing the measurement of average accessibility and equality of accessibility in the next section, we discuss how optimization models may be used to determine a theoretical maximum on the amount of improvement possible in reducing the average or providing a minimum access level while keeping the number of facilities the same. Section 3 applies these criteria to four states in the southeastern US, finding that improving the average (efficiency) usually also improves the lot of those with the worst access. However, if the goal is solely to guarantee a minimum level of service, we see equality of access improve at the expense of efficiency. Section 4 summarizes our findings and suggests future extensions of this research.

2. Development of criteria for the evaluation of hospital locations

This section first describes a number of criteria that are relevant in the evaluation of health care facilities and their location. It then develops measurable proxies for the criteria. The planned evaluation does not only include the direct comparison of a number of U.S. states on the aforementioned criteria, but it also includes the comparison of the situation present in those states and an optimized situation, which is obtained by relocating the existing number of hospitals at locations prescribed by optimization models.

The three main criteria considered in this work are

- the general efficiency,
- the service availability, and
- the equality of the locations.

Clearly, we need proxy expressions for these criteria in order to make them operational. As a measure of general efficiency, we will use the average distance (or time) between any potential patient and his closest hospital. Assigning patients to the hospitals closest to them appears somewhat arbitrary, but is not unusual. As the Dartmouth Atlas [9] states "As a result, when patients are admitted to hospitals, the admission generally takes place within a relatively short distance of where the patient lives." We will use this assumption of throughout this paper. The service availability may be measured as the proportion of the population (i.e., all potential patients) that is located within a prespecified distance D from their nearest facility. This is then the union of the "covering areas" of all hospitals in the state, where a potential patient is considered covered, if he is no farther than D from the closest facility. The notion of coverage was first introduced by Toregas et al. [39].

An obvious question is the magnitude of D. Many different values have been studied in the literature, depending on whether the time under consideration is a proxy for only the driving time from home to health care facility, or if it includes the entire notification–response–transportation cycle as would be the case when calling an ambulance. Carr et al. [5] provide an excellent analysis of actual times involved in this cycle. For example, 60 minutes from incident to arrival at a trauma center (the "Golden Hour") has been discussed as a potential time window that is crucial in trauma cases (e.g., [32]). We decided to use 30 minutes in this study as a goal, since our measurements will include only the final transportation phase of an ambulance trip, but can also be a proxy for driving times to seek non-emergent care. Bosanac et al. [3] made an early argument for this standard, providing a comprehensive literature review and application to the state of West Virginia. More recently, Carr et al. [5] examined the proportion of the U.S. population living within 30 minutes of an emergency department or a teaching hospital by modeling travel distances and times based on population density. Forrest and Starfield [15] found that travel times over 30 minutes reduced the likelihood of first contact care with a primary care physician. Frezza and Mazghebe [16] suggest a "golden period" of 30 minutes for the treatment of penetrating chest injuries, finding a dramatic difference in survivability at the 30-minute threshold. Note that all authors use travel time rather than distance, as distance is just a proxy for time. The usefulness of this proxy will be tested below.

Finally consider equity. While some consider equity to be broader than simply equality, also embodying other dimensions of fairness, justice, and neediness (e.g. [30,36]) most researchers treat them as equivalent for the purposes of measurement as equivalent, as do we. Refs. [38], [28] and [26] are the earliest works to consider the tradeoffs between efficiency and equity. Mulligan [29] and Marsh and Schilling [25] give excellent discussions of the wide variety of ways that equality (or inequality) has been measured, discussing the strengths and weaknesses of each. Measures such as the range of values and maximum absolute deviation are extremely sensitive to extreme values and ignore the interior of the distribution, while measures such as the variance are not normalized, and are thus incomparable between times or jurisdictions. We use a normalized measure that takes the entire distribution into

[1] Hurley et al. [21] state that "the majority of services rendered in emergency rooms has been for non-urgent care and that low income persons are disproportionate consumers of primary care in the emergency room".