# APPLICATIONS OF MANAGEMENT SCIENCE

*A Research Annual*

*Editor:* RANDALL L. SCHULTZ
*School of Management and Administration*
*The University of Texas at Dallas*

---

VOLUME 3 · 1983


JAI PRESS INC.

*Greenwich, Connecticut* *London, England*

*36 Sherwood Place*
*Greenwich, Connecticut 06836*

*JAI PRESS INC.*
*3 Henrietta Street*
*London WC2E 8LU*
*England*



*ISBN NUMBER: 0-89232-324-8*

*Manufactured in the United States of America*

# APPLICATIONS OF MANAGEMENT SCIENCE

*Volume 3* · 1983

# LIST OF CONTRIBUTORS


| | |
|---|---|
| *A. Cooper* | Kibbutz Settlement, Israel |
| *Roy L. Crum* | College of Business Administration, University of Florida |
| *Burton V. Dean* | Department of Operations Research, Case Western Reserve University |
| *Fred Glover* | School of Management, University of Colorado, Boulder |
| *D. Golan* | Kibbutz Settlement, Israel |
| *David P. Herron* | Senior Management Consultant, SRI International |
| *Charles L. Hubbard* | Department of Quantitative Methods, Georgia State University |
| *William R. King* | Graduate School of Business, University of Pittsburgh |
| *Darwin D. Klingman* | College of Business Administration, University of Texas at Austin |
| *Cynthia D. Leach* | Department of Operations Research, Case Western Reserve University |
| *Kamlesh Mathur* | Department of Operations Research, Case Western Reserve University |

*John Mote* — Analysis, Research and Computation, Austin, Texas

*A. Reisman* — Department of Operations Research, Case Western Reserve University

*K. Anthony Rhee* — Department of Quantitative Methods, Georgia State University

*R.JeanRuth* — School of Business Administration, University of Wisconsin, Milwaukee

*Harvey M. Salkin* — Department of Operations Research, Case Western Reserve University

*Virendra S. Sherlekar* — Solarex Corporation, Rockville, Maryland

*Ananth Srinivasan* — Graduate School of Business, University of Pittsburgh

*Lee A. Tavis* — College of Business Administration, University of Notre Dame

*David Whitman* — General Research Corporation, McLean, Virginia

*D. Yaron* — Faculty of Agriculture, The Hebrew University of Jerusalem

# PREFACE

The subject matter of *Applications of Management Science*, represented by the papers in Volume 3, is science applied to management decisions. This places management science squarely between the arenas of pure science and pure affairs. Scientists like physicists and mathematicians make inquiries into the nature of real phenomena. Acting as scientists, they have a legitimate mission of research. Managers, however, are people of affairs. But they also have a legitimate mission, namely, making decisions in the real world. How then do we assess the legitimacy of management science?

The question can be answered simply. First, let us exclude pseudo-science where researchers are more concerned with process rather than output, say by publishing—even in the best journals—without ever finding out anything of significance. Second, let us exclude pseudo-affairs where consultants play at making decisions without the responsibility of profit and loss. The legitimacy of management science can be found in what is left: real science *applied* to management.

The value of applications of management science, and hence management science, rests on this legitimacy. The quality of an application must be judged not by scientific or management criteria alone; it is inappropriate to do this since management science is neither. Rather, quality must be judged in different terms by asking whether a management science intervention (or paper on this topic) can, or indeed does, influence and improve management decision making. If so, we say that management science is successfully implemented. Thus, the key to management science legitimacy is implementation and improvement.

To some this idea will be novel. To others, including the founders of operations research, it is not. The purpose of this series is merely to show how the utilization of operations research, management science, decision science and management information and decision support system technology can improve decision making in organizations. This is what management science should be all about.

*Applications of Management Science* is an outlet for original research in management science and is distinguished by its form, its frequency of appearance, and its focus. The series is essentially a research anthology of papers that are substantive and may exceed the length limitations of traditional journal articles. Although any work dealing with the application of management science is appropriate, the "longer form" provides an outlet for papers that is not otherwise available. The series also provides an outlet for papers presented at symposia that are refereed to journal standards. The series includes both theoretical and methodological papers so long as they are extended toward application; in addition, comprehensive review articles are published. Excluded from *Applications of Management Science*, although appropriate for many other journals, are strictly theoretical or methodological developments, such as work on efficient algorithms. Also excluded are papers that do not directly concern decision making in organizations, such as the applied mathematics of sports.

All papers appearing in *Applications of Management Science* are refereed, and I am grateful to those who served as reviewers for each of the manuscripts in Volume 3. My primary debt, of course, is to the authors. By working at the boundary of theory and practice, they have helped to legitimize the mission of management science and to offer direct proof of its applicability to management decision making.

*Randall L. Schultz*
*Series Editor*

# CONTENTS

# MODELS FOR COORDINATING REGIONAL PLANNING OF HOSPITAL INPATIENT SERVICES WITH AMBULATORY CARE SERVICES

R. Jean Ruth

## ABSTRACT

The models discussed in this paper are designed as tools to aid in planning of hospital inpatient services by an individual facility, group of facilities, or regional planning agency, within the context of ambulatory care services. A framework is presented for planning in a region of the location and type of hospital inpatient services, given the availability and location of existing or planned ambulatory care services. Past models for planning hospitals or ambulatory care facilities are discussed in terms of this hierarchical planning framework. In the generalized model presented here, demand, as input to the model, is described in terms of geographical area, type and level of

**Applications of Management Science, Volume 3, pages 1–25.**

**ISBN: 0-89232-324-8**

service, and number of patient-days and number of physician visits required. The inpatient service at each existing or proposed hospital is described in terms of the number of beds, the location of the hospital, and the technological level of service as determined by the types of services and ancillary services available. An ambulatory care service is described in terms of the number of physician-equivalents, the location of the clinic, and the level of service. The purpose of the model is to analyze what changes should be made in services, with the output of the model in these same terms describing the services. These terms were selected to be consistent and representative of the measures used and data available for "bed need" planning now and in the past, thus facilitating implementation. The model and the terms selected are also designed to allow consideration of ambulatory care and other issues, such as conformance of inpatient services to standards, issues which have not been well incorporated into "bed need" planning techniques in the United States.

## 1. INTRODUCTION

Due to the visibility, high cost, and the necessity of hospital services and the long-term nature of capital investment for hospitals, much of the interest in health care facility planning has centered on hospitals as the linchpins of the health care delivery system. But detailed models of individual hospitals are not directly applicable to aggregate, long-term planning and such models have not been linked together with aggregate models to form a useful framework for planning in the United States. Further development of models and planning tools are needed to aid the health care facilities themselves as well as to aid regional or state agencies in proposing and evaluating changes to existing health care facilities. Since, for example, the utilization rate measured in patient-days per 1000 population has been much lower for persons treated by prepaid group practices or enrolled in health maintenance organizations (HMOs) than for the general population or those covered by Blue Cross, the consideration of ambulatory care in hospital planning may mean a reduction of hospital admissions without any degradation in the health status of the population. In any case, ambulatory care links the population and hospitals, where inpatient services provide "nonambulatory" care and physicians formally admit patients to the hospital to receive this care. The question is how to take ambulatory care into account in hospital planning.

The objective of this paper is to present a framework for planning to be used in identifying characteristics of hospital planning and appropriate models to support that planning; to present a model at an aggregate, strategic planning level which is expressed in terms of the basic decision variables (and available data) of hospital long-term planning—the number

of beds and the technological level (primary, secondary, and tertiary) of the service at each location; to incorporate ambulatory care into the model; and to structure the model in terms of the issues of effectiveness and efficiency faced by individual facilities, multiinstitutional facilities, advisory councils of facilities, and regional and state agencies. It is hoped that this paper will also encourage further work in the area.

As a conceptual framework for health planning models, the hierarchical planning framework of Anthony, as developed by Hax [23, 24] for the planning of production capacity, has been adapted. A hierarchical framework is useful here, as it is in production planning, to understand and analyze a large complex planning problem where different types of decisions are made at different levels and the scope and data availability also varies by level. The framework helps to put in perspective the models that have been proposed and the planning decisions to be made. There are three levels in the planning hierarchy: strategic planning, tactical planning, and operations control. We are concerned here with strategic planning, e.g., long-term planning for the region. The different levels of planning are summarized for hospital inpatient services and organized ambulatory care in Table 1. "Organized" ambulatory care includes outpatient clinics of hospitals and HMOs. In addition, there are also group practices and individual physicians providing ambulatory care in their offices. Hospital inpatient services are broadly categorized into medical–surgical, pediatric, and obstetric–gynecological. Here we consider medical–surgical services, although the model can also be used for other types of inpatient services. An inpatient service consists of the beds in the hospital allocated to the inpatients of the service and is supported by a variety of ancillary (e.g., lab, laundry) and administrative services. The number of beds limits the number of inpatients, since by definition an inpatient is assigned to a bed and has a length of stay in the service that is at least overnight. We will use *hospital* to mean an inpatient service at the hospital and *clinic* to mean the ambulatory care facility, whether outpatient clinic at a hospital, a separate clinic, a neighborhood health center, or other clinic.

An aggregate model is most appropriate for long-term planning of inpatient services since such planning involves the analysis and development of general guidelines; more detailed plans can be made as necessary and as more detailed data become available. Strategic planning, unlike tactical planning and operations control, may be implemented on a regional basis by a regional agency. A planner for a single facility would consider the population and other facilities in the region in its long-term planning, although his scope of planning would be somewhat narrower, concerned primarily with his own facility and its service area and the effect of possible proposals or of changes in the region over which it does

*Table 1.* Hierarchy for Regional Planning of Hospitals and Ambulatory Care Programs

| | *Strategic Planning* | *Tactical Planning* | *Operations Control* |
|---|---|---|---|
| Facility Planning | Regional Planning of Hospitals and Organized Ambulatory Care | Planning for Individual Hospital or Individual Ambulatory Care Program | Planning for Single Department in Hospital or Single Ambulatory Care Facility |
| Objective | Plan Resource Location and Acquisition, Type of Services, and Enrollment | Manpower and Resource Utilization (Budget and Price Structure) | Execution |
| Time Horizon | 5–10 Years | Yearly | Monthly or Weekly |
| Level of Management | Regional Planning Agency or Hospital Administration | Hospital or Program Administration | Administrative Asst. or Dept. Head |
| Scope | Region or Single Facility and its Service Area in Context of Region | Single Hospital and its Service Area or Single Ambulatory Care Program and its Target Population | Single Ambulatory Care Facility or Inpatient Department |
| Source of Information | Historical Data and Estimates for Hospitals and Ambulatory Care Facilities | Historical Data and Regional Plan for Hospitals and Ambulatory Care Facilities | Historical Data and Hospital Budget or Program Budget |
| Level of Detail | Very Aggregate | Aggregate | Very Detailed |
| Questions | Number and Level of Beds in Inpatient Service by Location; Location and Type of Services and Number of Ambulatory Care Visits | Allocation of Budget and Manpower | Scheduling of Personnel, Equipment and Patients |

not have control. Strategic planning analyses would be necessary for the individual facility to identify and select alternatives and to support their decisions before regulatory and planning agencies and to convince other facilities to consider, for example, merging or sharing services. Such planning would also be done by multiinstitutional or multihospital systems to generate alternatives involving capital investments and resource allocation in view of other complementary, substitutable, or competing sources of health care in the region. Hospitals are increasingly participating in various types of multiinstitutional sharing of services [49]. The methods of implementation of regional planning for hospitals include, for state agencies, certificate-of-need requirements and licensing of beds, and, for both regional agencies and individual facilities, persuasion, recommendations, and inquiries as to possible changes, e.g., joint services or mergers. The appropriateness and need for services are also considered by private insurance companies and governmental agencies in setting allowable charges and reimbursement of costs.

The high cost of hospitals, the concern that there should be appropriate and accessible hospital care, and the belief that the availability of hospital beds can create demand for these beds are all reasons that planning legislation and regulations have been enacted in various forms. The controversy over the validity of these reasons and the appropriateness and effectiveness of various regulations has led to a history of changes in regulations and regional agencies. But here we are concerned not with regulation as such but in developing tools to aid planning groups (whether a Health Systems Agency as mandated by P.L. 93–641 or a group within an individual facility or a multiple-facility system) in examining alternatives as part of policy development for the allocation of their resources in the region.

## 2. PAST WORK

We can use the planning hierarchy to categorize examples of work that have been done for health care facility planning and to relate this work to long-term planning. At the tactical level, many studies of overall manpower requirements and hospital budgeting and finance, as well as cost and population models of individual hospitals have been done, such as Coughlin's [10, 11]. Such studies are more detailed and are more concerned with shorter-term allocations of resources than are strategic planning decisions. There has also been much work on identifying cost and production functions of hospitals in general, although there are no generally agreed-upon conclusions on such issues as whether economies of scale do exist. (See Berki [4] and Feldstein [19].) At the operations level, many operations research approaches have been adapted for such areas

as manpower scheduling and inventory control; and Shuman et al. [45] and Stimson and Stimson [47] have critiqued many of these approaches. In particular, simulation models of hospital inpatient services have been developed for determining the number of beds needed and scheduling admissions to meet a given demand. However, such detailed models are for a single facility and a fixed service area and are not meant to consider the facility relative to the distribution of resources in the region.

At the strategic planning level, regional models have been developed separately for hospitals and for ambulatory care. In practice, regional hospital planning methodology has for the most part been concerned with finding a total regional bed need, as in the variations of the widely used Hill–Burton formula [32]:

$$\text{Number of beds needed in region} = \frac{\begin{array}{l}(\text{number of patient-days per 1000 population}) \\ \quad \times (\text{estimated population in 1000s for the} \\ \qquad \text{planning period})\end{array}}{\begin{array}{l}(\text{average occupancy per bed}) \\ \quad \times (\text{number of days in the planning period})\end{array}}.$$

Average occupancy is the average percentage of days in a year that a bed is actually filled, i.e., a patient admitted to the hospital is assigned to the bed. Clearly such a formula does not address any issues involving the distribution and location of facilities within the region, nor are technological level or conformance incorporated. Yet these issues are central to planning decisions.

Refinements of the simple formula approach have attempted to consider the capacity at each current location of the service needed to meet the demand of the population in the region. For example, Long and Feldstein [30] constructed an idealized model with a simple total cost function in order to determine an optimal number of the same-size hospitals which could be used as a guideline in a real region. Similarly, in this paper simple cost functions are proposed in order to initially determine guidelines on the distribution of resources needed in a region. Morrill with others [33–37; also 12, 17] developed a model based on a gravity function of use for matching demand in areas with facilities; that approach examined adding capacity to meet demand at each location or reallocating demand to existing locations—alternatives which involve both adding capacity and reallocating demand were not considered.

The Morrill approach is especially interesting in that it includes physicians as an intermediate step in receiving hospital care. This is of course accurate since an inpatient must be admitted by a physician. Thus it is appropriate, and arguably it is also necessary, to include ambulatory care in a model for regional hospital planning.

A mixed-integer programming model for planning of hospital inpatient

services in terms of the current configuration of hospitals, including level, location, and conformance, was developed by Ruth [38]. That initial model did not consider ambulatory services, and this paper is an adaptation, integration, and extension of that model and the other models. Other mathematical programming models have been proposed, such as the one by Barber et al. [3] for determining how many beds are needed within each area of a region, although in that model the current configuration of facilities and conformance to standards were not included nor were ambulatory care services considered. Various programming models of the health care system as a whole have been proposed, e.g., Calvo and Marks [7], Dokmëci [14], Schultz [40]. In these models the patients are in effect assigned to the nearest facility, and the object of the model is to find the set or pattern of locations to best serve the population. Yet, especially in urban areas, patients do not necessarily go the nearest facility, nor can they be forced to do so. Also the number of possible locations of hospitals can be effectively restricted to the existing hospitals and a few potential sites rather than considering all points in the region to be possible sites.

Although there has been discussion of guidelines for issues involved in planning ambulatory care [9, 31], the quantitative models proposed have primarily focused on selecting locations to maximize or ensure some specified utilization or enrollment (Abernathy and Hershey [2], Abernathy and Moore [1], and Dhillon's [13, 20] model). Much of the work done on ambulatory care is on manpower planning, which would be at the tactical level, and staffing and scheduling at the operations level. For example, Shuman et al. [44] and Schneider and Kilpatrick [41, 28] have developed manpower planning models, and Baum [5] developed a simulation model for a clinic in conjunction with a hospital. At the strategic level, Ittig [25, 26] constructed a linear programming model for determining the mix of ambulatory services to meet the specific demand of a target population at a particular location, such as a new HMO. Although the level of detail in these models is greater than that proposed here for the strategic level, we will adapt aspects of some of these models, e.g., as in Refs. 35, 37, 38, and 43. A major difference between earlier models such as Refs. 43, 44, and 3 and the treatment of ambulatory care in this paper is this model is expressed in terms of matching the population, as located in areas, to facilities. In the model here demand is viewed as having a source, and demand from each source must be met while satisfying constraints on distances.

## 3. CONCEPTUAL FRAMEWORK OF MODEL

The planning of hospital inpatient services in a region involves the allocation of resources among possible locations. We want to construct a