This study was done to develop a case mix management model, it demonstrated the effect case mix could have on the costs of reimbursing a contractor when contracting out patients.
A STUDY TO DEVELOP

A CASE MIX MANAGEMENT MODEL FOR COST EFFECTIVE
ALLOCATION OF OUTPATIENT WORKLOAD
BETWEEN MILITARY PHYSICIANS AND CONTRACT
PHYSICIANS IN THE OBSTETRICS AND GYNECOLOGY CLINIC
OF SILAS B. HAYS ARMY COMMUNITY HOSPITAL

A Graduate Research Project
Submitted to the Faculty of
Baylor University
In Partial Fulfillment of the
Requirements for the Degree
of
Master of Health Care Administration

by
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I. INTRODUCTION

Conditions Which Prompted the Study

The Obstetrics and Gynecology (OB-GYN) Clinic of Silas B. Hays Army Community Hospital provides a wide range of specialty health care to a population of approximately 34,351 female beneficiaries. The demand for outpatient care which this population places on the clinic has traditionally exceeded the clinic's appointment capability due to limitations on the amount of physician time available for outpatient care. This has led to long waits for appointments, encouraged inappropriate use of the emergency room, and generated dissatisfaction among the patients. To improve the access to care, the OB-GYN service considered an augmentation of their staff, either by hiring civilian physicians or by entering into a contractual arrangement with civilian physicians.

The opportunity to expand the OB-GYN staff was first presented in March 1985 as part of the Catchment Area Demonstration (CAD) Project, a Department of Defense test project for initiatives in military health care. The original scope of the CAD project granted the military hospital commander area management responsibility for both the military delivery system and for the services performed by civilian health care providers under the Civilian Health and Medical Plan of the Uniformed Services (CHAMPUS). An expanded OB-GYN Clinic offering evening and weekend appointments was among the clinical initiatives to be implemented under the CAD project.

Following a cancellation of CAD funding in late 1985, the Army Surgeon General's office maintained the concept of expanding OB-GYN outpatient services, incorporating this initiative as a specialty augmentation performed under civilian contract in one of two Primary Care for the Uniformed Services (PRIMIS) clinics to be established in the Fort Ord area. PRIMIS is a
concept under which a civilian provider contracts with the government to operate an outpatient clinic. The method for determining payment to the PRIMIS contractor, and the delineation of professional responsibilities between the OB-GYN component of the PRIMIS clinic and the Silas B. Hays OB-GYN clinic, are flexible and can be specified by the hospital commander. The PRIMIS clinic and the OB-GYN component are scheduled for implementation in fiscal year 1988 with contract proposals to be offered and evaluated in fiscal year 1987.

The Problem Statement

The issues to be considered in developing a contractual OB-GYN augmentation are first, the extent to which the contractor will provide services in terms of both numbers of appointments and types of appointments. Secondly, the cost implications of the contract based on the method of reimbursement to be selected. Both considerations will affect the final cost of the contract, and both will affect the functioning of the hospital's OB-GYN clinic, which will remain in operation. If, for example, the contractor were to be paid an equal fee for all visits, he would have an incentive to concentrate on uncomplicated visits of short duration, and produce a greater volume of visits. At the same time, the existing OB-GYN clinic would, by default, be asked to provide more resource intensive visits. Therefore, the problem to be resolved in this project is to produce a workload allocation model which will consider both of these issues and can allocate the OB-GYN visits between OB-GYN clinic physicians and contractor physicians at minimum cost. The model must also allow the OB-GYN clinic staff to reserve certain types and amounts of visits for allocation to the clinic staff in order to maintain clinical proficiency and for teaching purposes.
Objectives

Objective One: The visits for the OB-GYN clinic will be classified into case-mix groups, each with a medically relevant basis, and each with a basis for consumption of physician time, and the cost if referred to a contract provider.

Objective Two: A measure of the monthly demand for OB-GYN appointments will be made. This will be conducted for a three-month period of time using existing sources of workload data, and a one-month period using a special effort of prospectively recording appointment requests.

Objective Three: The availability of time the staff physicians make available for appointments will be determined. This will be done for the same three-month period used to estimate demand.

Objective Four: The cost per visit of using contract physicians will be estimated based on a review of the fee for service claims data from CHAMPUS.

Objective Five: The preferences of the OB-GYN staff will be sought to ensure they are allocated sufficient variety of cases they feel are necessary to maintain clinical proficiency and discharge teaching duties.

Objective Six: A linear programing model (LPM) will be formulated to allocate demand for OB-GYN appointments between staff and contract physicians.

Criteria

Criteria One: When used with demand data for visits, manpower data for staff physicians and cost data for contracting, the model must be able to recommend the case-mix of staff and contractor workload resulting in the lowest cost. The case-mix allocation recommended by the model must demonstrate lower cost than simply referring all patients to a contract physician after appointments with the staff are filled.
Criteria Two: The model must be able to demonstrate the changes in case-mix and contract costs among different methods of reimbursement for contract services.

Criteria Three: The model must also be capable of performing simulations to determine the impact of changes in key variables, such as price, demand, and manpower.

Assumptions

Assumption One: Sufficient space and equipment will exist to allow for the addition of staff or contract physicians.

Assumption Two: Under the PRIMIS guidelines, contract physicians must meet the same standards of training, licensure, and competence as staff physicians, and can therefore be considered as able to perform the same work as staff physicians to the same standard of quality.

Assumption Three: The OB-GYN portion of the PRIMIS clinic will be located in a facility currently used as a military outpatient clinic, and it is assumed patients will accept treatment by the contract physicians as they do with staff physicians.

Assumption Four: It is also assumed that the contractor will allow the hospital to manage the case-mix of the appointments referred to the contractor.

Assumption Five: Reductions in the size of the present OB-GYN staff are not anticipated, and replacement of the staff physicians with contract physicians is not being considered.

Limiting Factors

Limitation One: Defining the OB-GYN workload to be performed was strongly influenced by the hospital's operating philosophy of seeing all
patients who request treatment. Although a patient may have to wait for
an appointment, the hospital does not attempt to determine the necessity
of a patient's request for an appointment. The demand for service cannot,
therefore, be examined in terms of necessary versus unnecessary care. The
expressed demand of the patients for appointments is viewed as the demand
to be satisfied.

**Limitation Two:** The options for shifting this demand to other hospital
clinics is also restricted. The OB-GYN clinic does not restrict its opera-
tion to referrals from other providers; the hospital policy is to accept
OB-GYN appointment requests from patients without requiring screening by a
general medical clinic.

**Limitation Three:** Determining demand was also restricted by the Army's
workload reporting system. Under current regulations, clinical workload
represents visits for which both a demand was expressed and a resource
supplied. In situations where resources are insufficient to meet the
expressed demand, the unsatisfied demand is not required to be recorded.
A retrospective look at unsatisfied demand is restricted to obtaining
CHAMPUS data, which accounts for a portion of the demand by beneficiaries
which is not satisfied by the clinic. A prospective recording of unmet
demand could produce a more accurate historical record for defining work-
load, and was used to demonstrate a long-range solution towards implementing
this project's solution.

**Limitation Four:** A new Chief of the OB-GYN Service was appointed in
May 1986, and he is attempting to alter physician responsibilities to pro-
duce more time for clinic appointments. The extent to which his staff can
perform more clinic work will affect the cost and extent of using contractual
augmentation. The goal of the project, however, is not to develop a
definitive cost estimate based on resources, demand, or prices at one point in time. This study's allocation model is designed to be a dynamic tool, and is meant to incorporate new values such as increases in staff resources for clinic appointments. The changing of staffing policies which are being considered should not affect the development of this study, but will be a factor in any implementation of the study's model.

Limitation Five: An assessment of the cost of providing treatment with staff physicians was not made. The Uniform Chart of Accounts (UCA) is the only calculation available which measures the cost of treating outpatients at military medical treatment facilities. This report is based on average costs, and does not employ differentiation of costs by case-mix. Staff assets were assumed to represent a fixed cost which would not be subject to reduction based on the cost of contracting. The limitation in the decision process for allocating work between contractor and staff physicians is, therefore, confined to the variable costs of supplies used by the staff. The model does not measure the impact of the staff's case-mix on the variable costs of supplies. Since the staff will continue to be allocated maximum work up to their available time, the staff's workload, and therefore supply costs, will not be replaced by the contractor. The supply costs of treatment by the staff were therefore considered fixed and a system of calculation was not devised.

Related Research

The term "case-mix" has become accepted in health care literature to denote the classification of treatments with respect to various criteria. The classification process is designed to organize the health care output into manageable products and product lines for reimbursement, planning, quality control, budgeting, and research purposes.¹ The case-mix situation
in the OB-GYN study shares two areas of study with previous researchers: The use of a classification system for defining products, and the development of an approach to study and use the case-mix information to distribute workload in a manner which optimizes a specified value.

Concern over using health care costs stimulated researchers in the early 1970s to conduct studies of resource utilization and costs in providing inpatient care. Whether the researchers attempted to study health care delivery in one hospital, or to conduct comparative studies of several hospitals, they first had to develop a basis of measurement to standardize output data. Work on classifying treatments into groups was begun in order to reduce the thousands of combinations of diagnosis, procedures, and severity manifestations into data of a more manageable size. Output measures expressed as patient days and patient cases did not yield sufficient detail to explain variations in cost between hospitals. Much of the initial research was based on compiling groups based on diagnostic categories of the International Classification of Disease (ICDA). Evans and Walker took this approach to produce 98 groups based on ICDA and age/sex proportions. Other researchers, such as Bays, incorporated age/sex categories and multiple diagnosis with the ICDA classification.

The significance of this work in classifying workload and studying case-mix was shown by Zaretsky who demonstrated case-mix to be a highly important and statistically significant factor affecting hospital costs. The linking of case-mix and costs foreshadowed the era of prospective reimbursement, and the necessity of employing case-mix management in hospital strategic planning. The most significant work leading towards this situation was the Yale University study resulting in the creation of Diagnostic Related Groups (DRGs). Fetter, and the other Yale researchers who devised DRGs, envisioned
their DRG groups as a "manageable, medically interpretable set of case
types that allows one to control for differences in complexity attributable
to patient characteristics as described by age, primary diagnosis, secondary
diagnosis, primary surgical procedure and secondary surgical procedure."\(^5\)

Fetter, et al, saw the use of their classification system to assist regional
planners in defining the case-mix treatment responsibilities of area hospitals
based on demand and resource consumption factors.\(^6\) Fetter's assumption was
that within resource limitations, access and quality constraints can be met
with a number of alternative configurations of case-mix, with the least
costly alternative preferred.\(^7\) Furthermore, he recommended using linear
programming techniques to suggest the most efficient distribution of case-mix
configurations.\(^8\)

The Social Securities Amendments of 1983 (Public Law 98-21, Title VI)
established prospective payment for inpatient Medicare services, and used the
DRG classifications as the basis for determining reimbursement. This legis-
lation encouraged hospitals to adopt a product orientation in planning and
budgeting, using the DRG classification to establish manageable product
groups.\(^9\) By 1984, at least 40 case-mix systems were available in the health-
care marketplace\(^10\), although they were restricted to managing inpatient cas-
mix. Some systems were focused on short term requirements, such as assessing
immediate effects of prospective payment, while more complex systems inte-
grated costs, utilization reviews, clinical activities, and reimbursement,
to guide organizational planning and budgeting.

The literature has detailed three case-mix models which resemble the
model developed for the OB-GYN study. In the first of these, Goldfarb, et.al.,
described a nonlinear programming model with patients classified as necessary
or discretionary.\(^11\) Their objective was to maximize a nonlinear utility
function based on the number of patients, case-mix, quality of service, and
hospital income, constrained by available beds. Although a theoretical model, it is significant because it did not assume profit maximization as the sole objective. By incorporating trade-offs among various competing goals, both profit and policy related, Goldfarb, et al., offered a planning model which recognized the multidimensional character of hospital decision making.

Baligh and Laughhunn also incorporated nonfinancial considerations when they developed a linear model for case-mix allocation. Their objective was to maximize a weighted sum of a number of patients (classified by value to the hospital), subject to resource, patient, budgetary and policy constraints. Baligh and Laughhunn expressed a potential constraint as the minimum number of patients by class required to support teaching purposes. Other constraints such as goals for treating indigent patients were also presented. These noneconomic constraints influenced the value of the classes in the case-mix decision, and when combined with the economic constraints of resource consumption and budget, presented the hospital with a case-mix of optimum value which went beyond pure economic considerations.

The last linear programming model to be discussed was developed by Brandeau and Hopkins. Their goal was to develop a linear programming model which could examine the monetary and resource effects of marginal changes in case-mix, and the financial impact of changes in reimbursement schemes by certain payers. To examine both of these issues, Brandeau and Hopkins classified their patients into 14 groups, based on DRGs, intensity levels, and payer groups. Their formulation was expressed as:
\[
\max \sum_{j} (r_j - v_{c,j}) x_j \\
\text{subject to} \quad \sum_{j} a_{ij} x_j = b_i \quad i = 1,2,\ldots,m. \\
\text{and} \quad d_{\text{min},j} \leq x_j \leq d_{\text{max},j} \quad j = 1,2,\ldots,n.
\]

with the following variables:

\( j \) = index for classes of patients (by intensity and payer),
\( j = 1,2,\ldots,n; \)
\( i \) = index for departments/services, \( i = 1,2,\ldots,m; \)
\( x_j \) = number of patients of type \( j; \)
\( a_{ij} \) = average number of units of service \( i \) used by group \( j \) patient.
\( v_{c,j} \) = total variable cost incurred by patient of type \( j; \)
\( r_j \) = total revenue from patient of type \( j; \)
\( b_i \) = amount of service of \( i \) available;
\( d_{\text{min},j} \) = lower bound on demand for admission by patient type \( j; \)
\( d_{\text{max},j} \) = upper bound on demand for admission by patient type \( j. \)

This formulation is reproduced to illustrate linear programming considerations similar to that developed in the OB-GYN study. Brandeau and Hopkins' lower bound on patients (dmin) was developed to reflect the hospital's obligation to serve a given population, while the upper bound (dmax) represents the upper limit on patient demand. A similar bounding of demand was developed for the OB-GYN study to reflect requests for service (dmax) and requirements for teaching and clinical proficiency (dmin).

In a similar manner, this paper and the Brandeau and Hopkins study express the resource constraint of a department (b_i's) with the understanding it is more of a policy variable than a fixed constraint.\textsuperscript{14} Unlike the previous literature, the Brandeau and Hopkins model was implemented in a practical application. Stanford University Hospital used the model to negotiate Medicaid reimbursement levels in 1982, and to develop contract negotiation strategies with private insurance providers in 1982-83.\textsuperscript{15}
The Brandeau and Hopkins linear programming case-mix model, similar to the one used in this paper, was shown to be a valuable tool in providing planners with financial impact projections of different reimbursement schemes. The effective use of such information was derived from employing such a model in competitive bidding for various case mixes.

Lessons from the Literature

The output of medical care has been expressed by the literature in terms of diagnosis, prognosis, utilization, organ system, hospital department, patient demographic characteristic, and method of reimbursement. The selection of which of these criteria to employ in establishing case-mix groups should be guided by objectives. Although this permits wide latitude in developing classification schemes, certain attributes have been considered important to any classification scheme:

1. It must have clinical interpretability with relationships to diagnosis and operations.
2. Classes should be defined on variables commonly available on hospital abstracts, and relevant to output utilization.
3. The classes must be of a manageable number, and be mutually exclusive and exhaustive.
4. The classes should contain patients expected to utilize similar measures of output.

The case-mix management system using the classification should define the clinical outputs in terms of products, and should identify charges, statistics and costs associated with each product, identify the relationships between product mix and members of the medical staff, and facilitate involvement of the medical staff in planning, budgeting, and controlling health care operations. The completed case-mix model should be able
to perform a number of policy analyses using actual data and data hypothesized from future expectations. The value of performing such functions has been demonstrated in reimbursement contracting using a model based on a linear programming formulation. Thus far, publication of case-mix management research has been restricted to studies of inpatient treatment. The OB-GYN project will apply to the lessons learned in inpatient case-mix systems to develop an outpatient model capable of performing similar functions.

Project Methodology

The methodology is divided into three main areas: data collection, formulation of a linear programming model for case-mix allocation, and management applications. In the data collection phase, a determination of the case-mix groups and the patient demand within these groups will be presented. This will be followed by an examination of the OB-GYN staff resources which can be applied towards meeting the demand for service. The resource examination discussion will include consumption of physician time in providing care, the physician time available for providing care, and the policy guidelines which prioritize the application of the available physician time. The final data collection area to be presented is the cost of comparable services in the civilian community.

The formulation of the allocation model will describe the relationships among the relevant data variables described in the data collection phase. This will be followed by development of an objective function which will be formulated to result in the minimum cost of using contract physicians to meet the patient demand. The patient demand, unit costs of contracting, minimum staff workload, and staff physician resources will be used as constraints for the model.
The final portion of the discussion, management applications, will show how the model can be applied to compare alternative policies for contracting and using staff resources. A concluding section will summarize the potential value of implementing the model.
II. DISCUSSION

Data Collection

Case-Mix Groups. Prior to the collection of any data on the demand for OB-GYN outpatient services, a framework had to be developed within which the requests for this service could be classified and measured. This classification framework had to serve the patient by allowing an effective means to express the nature of the service requested, and had to assist the clinic by indicating the resources required to satisfy the request.

A classification system to meet these needs was developed and implemented in the OB-GYN clinic in 1984 as part of the Computerized Medical Record Information System (CMRIS), a test project for automating clinical information. All OB-GYN visits were classified into one of the following nine groups, each with an assigned length of appointment time:

<table>
<thead>
<tr>
<th>Group Number</th>
<th>Diagnostic Group</th>
<th>Abbreviation</th>
<th>Time Allocated Per Visit</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>PAP Smears</td>
<td>PAP</td>
<td>15 min.</td>
</tr>
<tr>
<td>2</td>
<td>New Obstetrical</td>
<td>NOB</td>
<td>20 min.</td>
</tr>
<tr>
<td>3</td>
<td>Routine Obstetrical</td>
<td>ROB</td>
<td>10 min.</td>
</tr>
<tr>
<td>4</td>
<td>Routine Gynecological</td>
<td>GYN</td>
<td>20 min.</td>
</tr>
<tr>
<td>5</td>
<td>Postpartum/Postoperative</td>
<td>PPV</td>
<td>15 min.</td>
</tr>
<tr>
<td>6</td>
<td>Colposcopy</td>
<td>CPC</td>
<td>30 min.</td>
</tr>
<tr>
<td>7</td>
<td>Ultrasound</td>
<td>UL</td>
<td>20 min.</td>
</tr>
<tr>
<td>8</td>
<td>Complicated Obstetrical</td>
<td>COB</td>
<td>20 min.</td>
</tr>
<tr>
<td>9</td>
<td>Histosalpingogram</td>
<td>HSG</td>
<td>30 min.</td>
</tr>
</tbody>
</table>

The groupings and time allocations represented above were the result of actual experience of the OB-GYN staff over the past four years. Both clinical interpretability (to include mutually exclusive and exhaustive classifying), and resource utilization (consumption of clinic time per visit) were considered in developing the groups. In the opinion of the OB-GYN staff, the time allocated per visit has been an accurate representation of the actual time employed. Nine groups of visits also represented a manageable size with which to plan the allocation of physician time.
and identify the demands of the patients.

**Establishing Total Demand for Service**

While CMRIS could provide data on the number of visits by group, this workload would only express the demand for services which was satisfied. A projection of the total demand for the OB-GYN clinic needed to include those visits would have been made if additional appointments had been available.

The first PRIMIS clinic in Fairfax, Virginia, unsuccessfully attempted to predict the total demand for general outpatient visits with a demographic approach. Predicted usage was forecast from both national usage per capita, and from per capita utilization of military medical facilities. In practice, the first PRIMIS clinic saw 40% to 50% more visits than demographically predicted. To improve the accuracy of workload predictions, two alternative approaches to measuring current demand were tried for the OB-GYN study: Historical data contained in CHAMPUS claims, and a prospective recording of requests for OB-GYN appointments.

**Demand Satisfied by CHAMPUS**

A computerized search of 1985 CHAMPUS claims data for the Fort Ord area was conducted to identify the extent to which the demand for outpatient GYN care was being met by local civilian providers. Procedure codes of the Physicians' Current Procedural Terminology, Fourth Edition (CPT-4) were used to sort the claims data into the case-mix groups used by the OB-GYN clinic for appointment scheduling. Providers are required to use the CPT-4 system to assign codes to visits as part of the CHAMPUS claims submission process. Using this approach, a total of 864 CHAMPUS outpatient GYN visits were identified for 1985. Obstetrical visits were not identified because CHAMPUS
considers prenatal, postnatal and the inpatient portion of an obstetrical episode to be one inpatient service. Individual outpatient visits for obstetrical care are not authorized for separate reimbursement, and are not recorded in the CHAMPUS database except for an occasional outpatient emergency visit.

Table 1 displays the results of the CHAMPUS claims search. Annual demand for visits satisfied through CHAMPUS was further specified for a three-month period of the fall for more detailed study. Fall was selected for more detailed study because it is a time of year when the military population is usually stable. The number of visits shown in Table 1 represented all claims which had been made as of March 26, 1986, which allowed a minimum of almost four months with which to account for pending claims. The number of visits in 1984 for these months is also shown to indicate the extent to which a delay in submitting claims may result in an understatement of the CHAMPUS visits. With the exception of October and November GYN visits, the difference in 1984 and 1985 claims for these months did not indicate a large difference in the number of CHAMPUS visits.
FT ORD AREA
OUTPATIENT OB-GYN CHAMPUS WORKLOAD

<table>
<thead>
<tr>
<th>Type of Visit</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
<th>1985, All Months</th>
</tr>
</thead>
<tbody>
<tr>
<td>PAP (1985)</td>
<td>5</td>
<td>12</td>
<td>7</td>
<td>226</td>
</tr>
<tr>
<td>(1984)</td>
<td>26</td>
<td>22</td>
<td>18</td>
<td></td>
</tr>
<tr>
<td>GYN (1985)</td>
<td>52</td>
<td>48</td>
<td>18</td>
<td>561</td>
</tr>
<tr>
<td>(1984)</td>
<td>60</td>
<td>81</td>
<td>62</td>
<td></td>
</tr>
<tr>
<td>CPC (1985)</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>15</td>
</tr>
<tr>
<td>(1984)</td>
<td>4</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>UL (1985)</td>
<td>6</td>
<td>2</td>
<td>0</td>
<td>58</td>
</tr>
<tr>
<td>(1984)</td>
<td>1</td>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HSG (1985)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>(1984)</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

Table 1

Comparison of 1984 and 1985 data suggests claim submission delays would not account for the low number of visits reported in Table 1. To see if the CHAMPUS claims in general are a low indicator of unmet demand by the OB-GYN clinic, CHAMPUS claims for care provided in November 1985 were selected for comparison with a prospective study of the OB-GYN clinic requests during the same month.

**Prospective Demand Measurement.** All requests for OB-GYN appointments received in November 1985 were recorded by the OB-GYN clinic appointment clerks on a prospective basis, and were recorded irrespective of whether an appointment was available or not. At the conclusion of the month, the number of OB-GYN appointments available was compiled from the clinic's daily schedule, and subtracted from the number of appointment requests.
The resulting workload is shown in Table 2. In two cases, UL and HSG visits, a surplus of available appointments is shown. This occurred because the appointments scheduled for these procedures were based on requests received in earlier months. Had the clinic schedule been made to satisfy demand expressed in November, clinic policy would have allocated surplus time to new obstetrical and complicated obstetrical visits. The adjusted unmet demand row of Table 2 reflects this redistribution and indicates the demand for visits expressed in November, which were not able to be satisfied by the available appointments.

<p>| NOVEMBER 1985 OB-GYN CLINIC VISITS |
|-----------------------------------|---|---|---|---|---|---|---|---|---|</p>
<table>
<thead>
<tr>
<th>Visits Requested</th>
<th>PAP</th>
<th>NOB</th>
<th>ROB</th>
<th>GYN</th>
<th>PPV</th>
<th>CPC</th>
<th>UL</th>
<th>COB</th>
<th>HSG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Requests</td>
<td>824</td>
<td>292</td>
<td>1020</td>
<td>796</td>
<td>288</td>
<td>69</td>
<td>13</td>
<td>614</td>
<td>5</td>
</tr>
<tr>
<td>Available</td>
<td>78</td>
<td>131</td>
<td>596</td>
<td>31</td>
<td>49</td>
<td>28</td>
<td>149</td>
<td>11</td>
<td>11</td>
</tr>
<tr>
<td>Unmet Demand</td>
<td>746</td>
<td>161</td>
<td>424</td>
<td>765</td>
<td>239</td>
<td>41</td>
<td>0</td>
<td>603</td>
<td>0</td>
</tr>
<tr>
<td>Adjusted Unmet Demand</td>
<td>746</td>
<td>88</td>
<td>424</td>
<td>765</td>
<td>239</td>
<td>41</td>
<td>0</td>
<td>531</td>
<td>0</td>
</tr>
<tr>
<td>Nov 85 CHAMPUS Visits</td>
<td>7</td>
<td>0</td>
<td>0</td>
<td>18</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Table 2.

Selection of Total Demand Data. Table 2 indicates that CHAMPUS claims represent a small fraction of workload which the OB-GYN clinic does not satisfy. CHAMPUS claims data did not, therefore, offer an accurate prediction of the workload the OB-GYN clinic would produce if resources for additional appointments had been provided. The CHAMPUS data may be too conservative for a variety of reasons: failure to report visits not exceeding the annual deductible fee; use of other insurance plans by the patient; or
ignorance of CHAMPUS procedures on the part of the patient. Prospective recording of appointment requests was a more accurate measure because it did not assume the patient's behavior or motivation for choosing where to receive care. The drawback of the prospective method is the possibility of recording repetitive requests from the same patient for obtaining a single appointment. Although this limitation is recognized, the prospectively determined total demand presented in Table 2 represents the most accurate data available, and will therefore be used in formulating and testing the study's allocation model.

**Staff Resources.** A listing of available OB-GYN clinic appointments for September, October and November 1985 was obtained from the CMRIS daily scheduling report. The staff physician resources available, expressed in minutes, were obtained by multiplying the number of available appointments by the time allocated per appointment. The results of these computations, shown in Table 3, indicates over a 50% reduction in clinic time from September to November. The variation in time allocated to clinic appointments was due to differences in inpatient workload, the use of compensatory time off by the physicians, and by the presence of holidays. Such circumstances make the prediction of an "average" month's work difficult to establish. More realistically, short range planning would consider factors such as these, and plan for supplemental coverage under the augmentation contract. Three months worth of resource data was obtained for use in studying the impact of various staffing levels such as these on the costs and use of contractual augmentation of the clinic.
### AVAILABLE STAFF PHYSICIAN TIME FOR THE OB-GYN CLINIC

<table>
<thead>
<tr>
<th>TYPE APPT</th>
<th>PAP</th>
<th>NOB</th>
<th>ROB</th>
<th>GYN</th>
<th>PPV</th>
<th>CPC</th>
<th>UL</th>
<th>COB</th>
<th>HSC</th>
<th>TOTAL TIME AVAILABLE</th>
</tr>
</thead>
<tbody>
<tr>
<td>TIME PER APPT (min)</td>
<td>15</td>
<td>20</td>
<td>10</td>
<td>20</td>
<td>15</td>
<td>30</td>
<td>20</td>
<td>20</td>
<td>30</td>
<td></td>
</tr>
</tbody>
</table>

#### Sep 85
- Appt Avail: 218, 236, 1075, 672, 112, 72, 21, 277, 5
- Time Avail: 3270, 4720, 10750, 13440, 1680, 2160, 420, 5540, 100, 47300 min.

#### Oct 85
- Time Avail: 2400, 3280, 7300, 9120, 1170, 1500, 320, 3820, 100, 29010 min.

#### Nov 85
- Appt Avail: 78, 131, 596, 300, 31, 49, 28, 149, 11
- Time Avail: 1170, 2620, 5960, 6000, 465, 1770, 560, 2980, 330, 21835 min.

Table 3.

The final aspect of utilization of physician resources is the prioritization of services provided. The OB-GYN clinic policy is to give greater emphasis to obstetrical care and those gynecological conditions which could lead to inpatient treatment. This general policy, however, must also provide for some care by the staff in all types of OB-GYN appointments in order to ensure clinical proficiency is maintained and for the training of physician residents. With a contractual augmentation, the staff physicians gain greater flexibility in diversifying the type of patients they may see. Under the PRIMIS concept, the professional qualifications of contract physicians and the care they provide must meet the standards of Army regulations, the Joint Commission on Accreditation of Hospitals, and national
professional standards. With these prerequisites, an assumption can be made that the contractor can be used in lieu of staff physicians for any OB-GYN appointment offered by the clinic. The guidelines for allocating workload between contractor and staff physicians were based on the cost of using contract physicians and the desires of the staff physicians to see a minimum number of appointments in the various case-mix groups. As an initial guide, the OB-GYN staff expressed a desire to see the following monthly minimum workload with staff physicians:

<table>
<thead>
<tr>
<th>Type of Appointment</th>
<th>Desired Minimum Staff Appointments/Month</th>
</tr>
</thead>
<tbody>
<tr>
<td>PAP</td>
<td>50</td>
</tr>
<tr>
<td>NOB</td>
<td>80</td>
</tr>
<tr>
<td>ROB</td>
<td>400</td>
</tr>
<tr>
<td>GYN</td>
<td>200</td>
</tr>
<tr>
<td>PPV</td>
<td>20</td>
</tr>
<tr>
<td>CPC</td>
<td>49</td>
</tr>
<tr>
<td>UL</td>
<td>7</td>
</tr>
<tr>
<td>COB</td>
<td>149</td>
</tr>
<tr>
<td>HSG</td>
<td>5</td>
</tr>
</tbody>
</table>

The diversity expressed by the minimum number of cases can also be altered to shape the nature of the clinic's scope of services, to take advantage of improvements in technology, or to take advantage of additional staff physicians.

Cost Alternatives. Two sources of additional physician resources were considered for use in augmenting the OB-GYN clinic's staff: permanent government service (GS) employed physicians and civilian physicians contracted to provide specified services. The GS authorization for additional physicians would be GS-14, step 1, and based on an annual salary of $59,010, and adding 10% for government paid benefits, the monthly cost of each additional GS physician would be $4,917.

There are three methods upon which the cost of contract physicians were calculated: The traditional fee for service, a set hourly rate for labor, and a set fee per visit. All three methods are being used in the
22

civilian healthcare market, and any one of the three could be selected as
the preferred reimbursement method for the contract to augment the OB-GYN
clinic. Table 4 shows the unit costs of the traditional fee for service
arrangement based on 1985 CHAMPUS claims for the Fort Ord area. Since
obstetrical care is not reimbursed by CHAMPUS on a per visit basis, estima-
tions of the unit cost for obstetrical visits were made using GYN visits of
comparable length: PAP approximating ROB and PPV visits, and GYN approxi-
mating NOB and COB visits. The second basis for contract reimbursement,
hourly rate for labor, is displayed in Table 5. Two hourly rates were used
to calculate unit costs based on the number of visits possible in an hour,
using the OB-GYN clinic's allocation time for appointments. The rates selected
for illustration are ones commonly used in the local civilian community for
staffing of acute care facilities. The final method, common fixed price for
all visits, is the method employed in the PRIMIS clinic established in Fairfax,
Virginia. The PRIMIS project officer for the Army Surgeon General's Office
has estimated that the per visit cost in a PRIMIS clinic at Fort Ord would
be $50.14. This reimbursement method does not differentiate the length
or complexity of a visit in determining reimbursement. Contractors assume
the profit on some visits will offset the losses on others.

Formulation of the Allocation Model
Specification of the Variables

This model was developed to examine a series of alternative configura-
tions of case-mix allocations between staff and contract physicians, and
within resource limitations, to produce the least costly alternative. The
model variables developed for use in formulating the model are:
1985 CHAMPUS UNIT COSTS, FORT ORD AREA

<table>
<thead>
<tr>
<th>Type Visit</th>
<th>Average Fee for Service</th>
<th>Number of Visits</th>
<th>Standard Deviation</th>
<th>Maximum Fee</th>
<th>Minimum Fee</th>
</tr>
</thead>
<tbody>
<tr>
<td>PAP</td>
<td>$10</td>
<td>226</td>
<td>$3</td>
<td>$26</td>
<td>$4</td>
</tr>
<tr>
<td>NOB</td>
<td>43</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>ROB</td>
<td>10</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>GYN</td>
<td>43</td>
<td>561</td>
<td>25</td>
<td>190</td>
<td>10</td>
</tr>
<tr>
<td>PPV</td>
<td>10</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>CPC</td>
<td>76</td>
<td>23</td>
<td>20</td>
<td>100</td>
<td>48</td>
</tr>
<tr>
<td>UL</td>
<td>87</td>
<td>49</td>
<td>52</td>
<td>163</td>
<td>25</td>
</tr>
<tr>
<td>COB</td>
<td>43</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>HSG</td>
<td>98</td>
<td>5</td>
<td>49</td>
<td>150</td>
<td>55</td>
</tr>
</tbody>
</table>

Table 4.

OB-GYN UNIT COSTS BASED ON HOURLY CHARGES

<table>
<thead>
<tr>
<th>Type Visit</th>
<th>Unit Cost @ $100 Hr</th>
<th>Unit Cost @ $150 Hr</th>
</tr>
</thead>
<tbody>
<tr>
<td>PAP</td>
<td>$25</td>
<td>$38</td>
</tr>
<tr>
<td>NOB</td>
<td>33</td>
<td>50</td>
</tr>
<tr>
<td>ROB</td>
<td>17</td>
<td>25</td>
</tr>
<tr>
<td>GYN</td>
<td>33</td>
<td>50</td>
</tr>
<tr>
<td>PPU</td>
<td>25</td>
<td>38</td>
</tr>
<tr>
<td>CPC</td>
<td>50</td>
<td>75</td>
</tr>
<tr>
<td>UL</td>
<td>33</td>
<td>50</td>
</tr>
<tr>
<td>COB</td>
<td>33</td>
<td>50</td>
</tr>
<tr>
<td>HSG</td>
<td>50</td>
<td>75</td>
</tr>
</tbody>
</table>

Table 5.
C = Total cost of visits performed by contract physicians in the period studied.

S = Savings realized by performing care with staff resources.

d_i = Total demand for appointments for group_i during the period studied.

t_i = Amount of physician time allocated per visit for group_i.

y_i = Number of visits in group_i allocated to the staff to be performed in the period examined.

m_i = Minimum number of visits in group_i which the staff desires to perform in the period examined.

T = Total number of minutes of staff time available for clinic use in the period examined.

C_i = Unit cost per group_i visit referred to a contract physician.

The Objective Function

The objective of the clinic is to meet the demand for visits by employing its staff in a manner which makes the least expensive use of contract physicians. This is stated:

\[ \text{MIN } C = \sum_{i=1}^{9} C_i (d_i - y_i) \]

Stating the objective function in this manner directly conveys the thrust of the model: To favor the allocation of work to the staff, resulting in minimizing of the contract cost. Although clearly indicating the model's purpose, this formulation does not directly state the number of contractor visits, but produces this value by an additional step of subtracting staff work from demand. This results in a very long objective function when the actual values are inserted and the computations are begun for obtaining a solution. The mathematical efficiency of the model was improved by restating the objective function as:

\[ \text{MAX } S = \sum_{i=1}^{9} C_i y_i \]
Expressing the objective function as a savings maximizer is the equivalent of expressing a cost minimizer, but offers a formulation which is more efficiently manipulated because it eliminates a subtraction process which indirectly defines the number of contractor visits.

Constraints

The availability of staff time for the clinic, the minimum work for the staff's proficiency and training, and the number of visits requested (total demand), constrained the model's solution. The objective function was therefore constrained:

subject to: \( m_i \leq y_i \leq d_i \)

and \( \sum_{i=1}^{n} t_i y_i \leq T \)

The Completed Formulation

The formulation for solution, using fee for service cost coefficients, November 1985 resource and demand variables, and the minimum workload requested by the staff, is expressed:

\[
\text{MAX } S = 10Y_1 + 43Y_2 + 10Y_3 + 43Y_4 + 10Y_5 + 6Y_6 + 87Y_7 + 43Y_8 + 98Y_9
\]

(Coefficients indicate cost per case referred to)

(Contractors)

\[
\text{SUBJECT TO: } Y_1 \geq 50
\]

\[
Y_2 \leq 80
\]

\[
Y_3 \leq 400
\]

\[
Y_4 \leq 200
\]

\[
Y_5 \leq 20
\]

\[
Y_6 \leq 49
\]

\[
Y_7 \leq 8
\]

\[
Y_8 \leq 254
\]

\[
Y_9 \leq 5
\]

Minimum Staff Work Constraints
The $Y_i$ variables represent workload performed by staff physicians for the following groups: $Y_1$ (PAP), $Y_2$ (NOB), $Y_3$ (ROB), $Y_4$ (GYN), $Y_5$ (PPV), $Y_6$ (CPC), $Y_7$ (UL), $Y_8$ (COB), and $Y_9$ (HSG).

Management Applications

Linear Programming Allocations. The solutions to the model's equations were arrived at using an IBM personal computer running LINDO (Linear, Interactive, Discrete Optimizer), a commercially available computer program for solving linear, integer, and quadratic problems.

Before presenting any linear programming solutions for discussion, however, the value of case-mix management must first be established. To do this, the OB-GYN clinic demand data for November 1985, presented earlier in Table 2, was used to calculate the cost of referring the unsatisfied appointment requests for that month to the contract physicians. No attempt was made to alter the types of appointments which the OB-GYN clinic had scheduled. The costs of referring workload without altering the nature of the OB-GYN clinic practice is shown in Table 6. Costs were calculated for the three methods of reimbursing contractors discussed earlier. The Linear Programming Model (LPM) was then used to run the same data and determine the extent to which the model's recommended allocation could

\[
15Y_1 + 20Y_2 + 10Y_3 + 20Y_4 + 15Y_5 + 30Y_6 + 20Y_7 + 20Y_8 + 30Y_9 \leq 21853 \quad \text{(Resource Consumption per visit and Total Staff Time Availability Constraint)}
\]
Table 6

<table>
<thead>
<tr>
<th></th>
<th>$142096.76</th>
<th>$79535</th>
<th>$130603</th>
<th>Total Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td>26624.74, 74</td>
<td>531, 83</td>
<td>2723, 83</td>
<td>22833, 83</td>
<td>83</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>13</td>
</tr>
<tr>
<td>2055.74, 74</td>
<td>4, 14</td>
<td>357, 82</td>
<td>769, 34</td>
<td>765</td>
</tr>
<tr>
<td>11983.46</td>
<td>23, 49</td>
<td>293, 49</td>
<td>2390, 29</td>
<td>49</td>
</tr>
<tr>
<td>38357.10</td>
<td>76, 76</td>
<td>765, 61</td>
<td>769, 76</td>
<td>765</td>
</tr>
<tr>
<td>2129, 36</td>
<td>44, 44</td>
<td>728, 44</td>
<td>724, 92</td>
<td>924</td>
</tr>
<tr>
<td>4412.32</td>
<td>204, 204</td>
<td>378, 204</td>
<td>378, 88</td>
<td>88</td>
</tr>
<tr>
<td>4746, 47</td>
<td>78, 78</td>
<td>18650, 78</td>
<td>18650, 78</td>
<td>78</td>
</tr>
</tbody>
</table>


NOV 85 O.G.CN DEMAND WITHOUT LINEAR PROGRAMMING ALLOCATION OF APPOINTMENTS
more efficiently employ the OB-GYN clinic resources and reduce contract costs. The LPM simulations were successful in allocating the total demand while still meeting the OB-GYN staff's requirement for diversity of work. Appendices C, D and E contain the actual simulation results of this examination, and the results are summarized in Table 7. In a cost comparison of the LPM and non LPM allocations (Table 8), the LPM produced a less costly case mix than the nonprogramed approach for all of the reimbursement options. With cost reductions of 14.5%, 13% and 54% over the nonprogramed case-mix allocation, the LPM could produce significant savings if adopted for use in managing the clinic and contractor's case-mix. Having demonstrated the LPM as a potentially valuable approach in recommending case-mix allocations, the model was used to address some of the management questions which were alluded to earlier.

Comparison of Reimbursement Options. In Table 8, the LPM showed it could be used to calculate the cost of different reimbursement methods, given the most cost efficient case-mix per method. While this is certainly a major consideration in establishing an augmentation contract, the demonstration of the model was not made using prices offered by potential contractors. When the offer to bid on the contract is issued in 1987, the proposal offer could ask potential contractors to submit bids under any or all of the reimbursement methods. The first advantage of using the LPM in such a circumstance is to quickly calculate the expected costs of the various prices and reimbursement methods submitted by the bidders.

If Table 8 is examined more closely, another advantage of the LPM can be seen. Recommendations to select the least costly reimbursement method differ between the LPM and nonprogramed allocation approaches. This occurs because if the LPM is used to evaluate the cost of contract proposals,
NOV 85 OB-GYN DEMAND ALLOCATED BY LINEAR PROGRAMING

<table>
<thead>
<tr>
<th>Case-Mix Group</th>
<th>Fee for Service Contract</th>
<th>$100 Hourly Contract</th>
<th>Flat Fee $50.14 per Visit</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Staff Appts</td>
<td>Contractor Appts</td>
<td>Contract Costs</td>
</tr>
<tr>
<td>PAP</td>
<td>50</td>
<td>774</td>
<td>$7740</td>
</tr>
<tr>
<td>NOB</td>
<td>262</td>
<td>30</td>
<td>1290</td>
</tr>
<tr>
<td>ROB</td>
<td>400</td>
<td>620</td>
<td>6200</td>
</tr>
<tr>
<td>GYN</td>
<td>200</td>
<td>596</td>
<td>25628</td>
</tr>
<tr>
<td>PPV</td>
<td>20</td>
<td>268</td>
<td>2680</td>
</tr>
<tr>
<td>CPC</td>
<td>69</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>UL</td>
<td>13</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>COB</td>
<td>254</td>
<td>360</td>
<td>15480</td>
</tr>
<tr>
<td>HSG</td>
<td>5</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>Total Costs</strong></td>
<td></td>
<td></td>
<td><strong>$59018</strong></td>
</tr>
</tbody>
</table>

Table 7.
COST COMPARISON OF LINEAR PROGRAMING MODEL AND NONPROGRAMED CASE-MIX ALLOCATIONS FOR NOV 85 OB-GYN DEMAND

<table>
<thead>
<tr>
<th>Reimbursement Method</th>
<th>Contract Costs Nonprogramed Allocation</th>
<th>Contract Costs LPM Allocation</th>
<th>LPM Cost Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Fee for Service Contract</td>
<td>$130,603</td>
<td>$59,018</td>
<td>54%</td>
</tr>
<tr>
<td>$100 Hourly Rate Contract</td>
<td>$79,555</td>
<td>$68,921</td>
<td>13%</td>
</tr>
<tr>
<td>Flat Fee, $50.14 Per Visit Contract</td>
<td>$142,097</td>
<td>$121,489</td>
<td>14.5%</td>
</tr>
</tbody>
</table>

Table 8.

it can incorporate changes in staff utilization as part of the cost calculations. Without such a process, the contractor's case-mix at the proposed prices cannot be evaluated for cost reduction except for changing the proposed prices, or roughly estimating possible reductions which could be made in some of the referred work. Thus, beyond a single comparison of reimbursement proposals, the LPM allows managers an opportunity to search for areas to reduce the cost of proposed contracts which exceed the augmentation budget.

**Increasing Staff Productivity.** The basic assumption in considering a contract for additional resources is that the demand exceeds the manpower resources the OB-GYN clinic staff has available. The extent to which the contractor is used varies directly with the amount of time the OB-GYN staff can devote to the clinic. In the earlier discussion on staff resources, large fluctuations in staff availability were displayed in Table 3. Staff fluctuations can sometimes be predicted, such as vacations planned during holiday seasons, or the reduction in inpatient duties caused by renovation of the
operating rooms. In such cases, management would desire to assess the impact of additional or reduced staffing on the budget for the contractual augmentation. To examine the LPM's usefulness in this application, the previously described simulations run with November 1985 data were re-run using the 47,300 minutes of staff time available in September 1985 in lieu of the 21,835 minutes available in November 1985. The simulations contained in Appendices F, G, H and summarized in Table 9 again displayed the model's ability to provide the impact on contract costs and case-mix when staff resources change.

Another staffing application of the model is to simulate the results if the clinic staff were augmented by a combination of contract physicians and additional civilian employee physicians. To demonstrate this, the November 1985 demand and resources were again used as the basic data. In this simulation, the staff resource time was increased to 39,133 minutes, which reflects the addition of two Full-Time Employee (FTE) Physicians working an eight hour day. The LPM was run (Appendices I, J, K) to see the cost differences between the combined augmentation approach and an augmentation dependent solely on contract physicians. The results, presented in Table 10, shows the cost of contractors, the cost of additional FTEs (based on the GS-13 salaries discussed earlier), and the total cost of the combined augmentation for each of the three reimbursement methods. For comparative purposes, the costs of augmenting with contract physicians alone was reproduced from Table 7, and placed below the combined augmentation costs. The LPM has, therefore, shown its ability to compare the costs of using additional staff resources with contract resources in both an either/or situation, and in combination.

Sensitivity Analysis. The accuracy of the LPM forecasts and recommendations depend on the accuracy of the data entered into the model. In the
<table>
<thead>
<tr>
<th>Case Mix Group</th>
<th>Fee for Service Contract</th>
<th>$100 Hourly Contract</th>
<th>Flat Fee $50.14 per Visit</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Staff Appts</td>
<td>Contractor Appts</td>
<td>Contract Cost</td>
</tr>
<tr>
<td>PAP</td>
<td>50</td>
<td>774</td>
<td>$7740</td>
</tr>
<tr>
<td>NOB</td>
<td>292</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>ROB</td>
<td>973</td>
<td>47</td>
<td>470</td>
</tr>
<tr>
<td>GYN</td>
<td>796</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>PPV</td>
<td>20</td>
<td>268</td>
<td>2680</td>
</tr>
<tr>
<td>CPC</td>
<td>69</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>UL</td>
<td>13</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>COB</td>
<td>614</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>HSG</td>
<td>5</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>Total Costs</strong></td>
<td></td>
<td></td>
<td>$10890</td>
</tr>
</tbody>
</table>

Table 9.
<table>
<thead>
<tr>
<th>Case Mix Group</th>
<th>Ave Fee for Svc</th>
<th>$100 Hourly Contract</th>
<th>Flat Fee $50.14 per Visit</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Staff Appts</td>
<td>Contractor Appts</td>
<td>Staff Appts</td>
</tr>
<tr>
<td>PAP</td>
<td>50</td>
<td>744</td>
<td>24</td>
</tr>
<tr>
<td>NOB</td>
<td>292</td>
<td>0</td>
<td>80</td>
</tr>
<tr>
<td>ROB</td>
<td>400</td>
<td>620</td>
<td>1020</td>
</tr>
<tr>
<td>GYN</td>
<td>674</td>
<td>122</td>
<td>200</td>
</tr>
<tr>
<td>PPV</td>
<td>20</td>
<td>268</td>
<td>234</td>
</tr>
<tr>
<td>CPC</td>
<td>69</td>
<td>0</td>
<td>69</td>
</tr>
<tr>
<td>UL</td>
<td>13</td>
<td>0</td>
<td>8</td>
</tr>
<tr>
<td>COB</td>
<td>614</td>
<td>0</td>
<td>254</td>
</tr>
<tr>
<td>HSG</td>
<td>5</td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>21566</strong></td>
<td><strong>40054</strong></td>
<td><strong>60517</strong></td>
</tr>
<tr>
<td><strong>FTE Cost</strong></td>
<td><strong>9834</strong></td>
<td><strong>9834</strong></td>
<td><strong>9834</strong></td>
</tr>
<tr>
<td><strong>Combined Augmentation</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total Cost</strong></td>
<td><strong>31400</strong></td>
<td><strong>49888</strong></td>
<td><strong>70351</strong></td>
</tr>
<tr>
<td><strong>Cost of Contractors Alone</strong></td>
<td><strong>59018</strong></td>
<td><strong>68921</strong></td>
<td><strong>121489</strong></td>
</tr>
</tbody>
</table>

Table 10.
simulations previously presented, the model was used to demonstrate how it could predict the outcome of various conditions which management might foresee occurring. A sensitivity analysis of the model's results was also conducted to demonstrate the degree of error which would be acceptable before the case-mix allocation would be altered.

The LINDO program was used to perform a sensitivity analysis of all of the coefficients of the model's variables in each of the simulations which were run, and the results were made a part of the appendices containing the simulation solutions. Table 11 was constructed to show the usefulness of conducting an analysis, using demand coefficients. The allowable increases shown in the table indicate the extent to which the demand can increase before the case-mix of the work allocated to the staff would change. Underestimation of the demand would have no impact on the case-mix allocations for the staff in 6 of the 9 case-mix groups showing increase to INFINITY. In the remaining 3, the estimation error would have to be large before a change occurred. If fewer requests for appointments are made than expected, the allowable decrease column indicates the point at which the expected demand can be reduced before it reaches the minimum work the staff wishes to perform, or the point at which a recalculation of the case-mix would be required. Use of the sensitivity analysis indicated the parameters within which the error of estimating correct values would alter the solution. If it is not likely that the allowable changes will be reached, the LPM allocation can be implemented. In cases where it is reasonably expected that actual practice will exceed the allowable values, additional simulations can be run to forecast the impact if these limits are exceeded.
# Sensitivity Analysis of Demand for Nov 85 OB-GYN LPM Case-Mix Allocations

<table>
<thead>
<tr>
<th>Case-Mix Group</th>
<th>Current Coefficient (Demand)</th>
<th>Allowable Increase</th>
<th>Allowable Decrease</th>
<th>Staff Appts Allocated</th>
<th>Staff Minimum Workload</th>
</tr>
</thead>
<tbody>
<tr>
<td>PAP Y1</td>
<td>824</td>
<td>Infinity</td>
<td>774</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>NOB Y2</td>
<td>292</td>
<td>Infinity</td>
<td>30</td>
<td>262</td>
<td>80</td>
</tr>
<tr>
<td>ROB Y3</td>
<td>1020</td>
<td>Infinity</td>
<td>620</td>
<td>400</td>
<td>400</td>
</tr>
<tr>
<td>GYN Y4</td>
<td>796</td>
<td>Infinity</td>
<td>596</td>
<td>200</td>
<td>200</td>
</tr>
<tr>
<td>PPV Y5</td>
<td>288</td>
<td>Infinity</td>
<td>268</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>CPC Y6</td>
<td>69</td>
<td>121</td>
<td>20</td>
<td>69</td>
<td>49</td>
</tr>
<tr>
<td>UL Y7</td>
<td>13</td>
<td>182</td>
<td>5</td>
<td>13</td>
<td>8</td>
</tr>
<tr>
<td>COB Y8</td>
<td>614</td>
<td>Infinity</td>
<td>360</td>
<td>254</td>
<td>254</td>
</tr>
<tr>
<td>HSG Y9</td>
<td>5</td>
<td>121</td>
<td>0</td>
<td>5</td>
<td>5</td>
</tr>
</tbody>
</table>

Table 11.
III. CONCLUSIONS AND RECOMMENDATIONS

Conclusions

A linear programming model was developed which allocated workload of the OB-GYN clinic between staff physicians and contract physicians. The allocation was made by managing a case-mix of the various types of visits to produce a recommended mix which incurred the least cost to the government. The model considered the availability of the staff physicians' time, the consumption of time per visit, minimum work needed for clinical proficiency, and the cost of referring visits to a contractor. The model was demonstrated as a tool to be used in evaluating the cost of various reimbursement options which could be proposed under an augmentation contract. Finally, the model was shown to demonstrate various changes in cost and workload which would result if prices, staffing, or demand were altered.

Results which were produced by using the model were compared with the results of nonprogramed case-mix allocations, and were shown to be more cost-efficient. The model was, therefore, shown to be a valuable tool which can be employed late next year when the hospital enters into contracting procedures for the OB-GYN component of the PRIMIS clinic. In order to demonstrate the model's usefulness, an attempt was made to gather as much realistic data as possible on demand for service, civilian prices for comparable care, and the availability of staff physician resources. Reliable data was easily obtained in all areas but the estimation of demand for appointments.

The comparison of CHAMPUS claims data with the volume of appointment requests made to the OB-GYN clinic showed that CHAMPUS accounted for a small portion of the demand to be satisfied. Neither the CHAMPUS summary
reports, nor a detailed CHAMPUS claims review such as the one conducted for this study, produced a reliable estimate to plan for the amount of OB-GYN clinic services which had to be provided. It was also learned that the Army's workload reporting system could only be used as an estimate of the minimum workload to be satisfied, since it did not account for requests in excess of available appointments. Whether or not the LPM is adopted in planning and managing for augmentation of staff physicians, a procedure to account for unsatisfied demand is needed. After the attempt to use CHAMPUS and the standard Army workload accounting data failed to produce a sufficient measure of total demand, a prospective recording of appointment requests for the OB-GYN clinic was made for one month. This method indicated far more demand than the CHAMPUS data or the clinic's workload data. Although the LPM can be employed without using prospectively recorded demand data, the effectiveness of the model will be enhanced with more accurate data. Finally, the ability to develop or implement a case-mix management system has been made possible by the increased access to computers by middle and lower level management personnel. The decision to adopt the case-mix model developed in this study will also require the acceptance of automated decision-making aids in the daily practice of management.

Recommendations

A recommendation has been made to the OB-GYN clinic to record the number of requests for appointments which were not able to be satisfied. This information will be of great importance in planning for the extent of augmentation by a civilian contractor. It was also recommended that the OB-GYN clinic perform the appointment scheduling for the OB-GYN component of the PRIMIS clinic. This study demonstrated the effect case-mix could
have on the costs of reimbursing a contractor. The scheduling of appointments for both the OB-GYN clinic staff and the OB-GYN contract physicians could ensure patients obtained the earliest appointment available, ensure effective use of staff physicians, and reduce the costs of contracting the services.
FOOTNOTES


6Ibid. p. 36.

7Ibid. p. 37.

8Ibid. p. 37.


10Ibid. p. 28.

11Marsha Goldfarb; Mark Hornbrook; and John Rafferty, "Behavior of the Multiproduct Firm, A Model of the Nonprofit Hospital System" Medical Care, Vol. 18, No. 2 Feb 1980. pp. 185-201.


14Ibid. p. 33.

15Ibid. p. 43.


17Ibid. p. 3.

21 Ibid. p. 43.


24 Ibid.

APPENDIX A

DEFINITIONS
APPENDIX A

Definitions

**CAD:** Catchment Area Demonstration Project, a CHAMPUS test project at Fort Ord designed to allow the hospital commander to explore alternative delivery systems and reduce CHAMPUS costs. The project began in March, 1984, and lost funding in December, 1985.

**PRIMIS:** Primary Care for the Uniformed Services. A concept of using a civilian contractor to establish and operate a primary care outpatient clinic for patients entitled to military health benefits.

**CASE-MIX:** A classification of patient care workload grouped by category of payment, severity of condition, consumption of resources, or other criteria, manageable product lines for planning, budgeting and reimbursement purposes.

**LPM:** Linear Programing Model; a linear programing formulation designed to maximize a value or minimize a value, using an automated process based on the SIMPLEX technique.

**CMRIS:** Computerized Medical Record Information System. An automated appointment and outpatient record system used in the OB-GYN clinic. The system captures clinical and administrative data concerning patient encounters.

**CASE-MIX GROUP ABBREVIATIONS:**

- **PAP:** Pap Smear
- **NOB:** New Obstetrical Visit
- **ROB:** Routine Obstetrical Visit
- **GYN:** Gynecological Visit
- **PPV:** Postpartum/Postoperative Visit
- **CPC:** Colposcopy
- **UL:** Ultrasound
- **COB:** Complicated Obstetrical Visit
- **HSG:** Histosalpingogram

**LINDO:** Linear, Interactive, Discreet Optimizer; a computer program by LINDO Systems, Inc., used to run the linear programing formulations in this study.
APPENDIX B

SAMPLE LINDO REPORT
Coefficients in the objective function represent the cost per visit if performed by contract physicians.

Right hand values of rows 2 thru 10 are the minimum cases to be allocated to staff physicians.

Right hand values of rows 11 thru 19 represent total number of visits (demand) to be allocated.

Coefficients in row 20 are the number of minutes needed per visit; the right hand value is the number of staff physician minutes available.

SOLUTION: The values in the VALUE column represents the number of visits to be allocated to staff physicians.

* equals cost savings by using staff vs. total contracting.

Case-Mix Variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>Case-Mix Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Y1</td>
<td>Pap Smear</td>
</tr>
<tr>
<td>Y2</td>
<td>New Obstetrical</td>
</tr>
<tr>
<td>Y3</td>
<td>Routine Obstetrical</td>
</tr>
<tr>
<td>Y4</td>
<td>Gynecological</td>
</tr>
<tr>
<td>Y5</td>
<td>Postpartum/Operative</td>
</tr>
<tr>
<td>Y6</td>
<td>Colposcopy</td>
</tr>
<tr>
<td>Y7</td>
<td>Ultrasound</td>
</tr>
<tr>
<td>Y8</td>
<td>Complicated Obstetrical</td>
</tr>
<tr>
<td>Y9</td>
<td>Histosalpingogram</td>
</tr>
</tbody>
</table>

Ranges in which the basis is unchanged:

<table>
<thead>
<tr>
<th>VARIABLE</th>
<th>CURRENT</th>
<th>ALLOWABLE</th>
<th>ALLOWABLE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Y1</td>
<td>10.000000</td>
<td>INFINITY</td>
<td>INFINITY</td>
</tr>
<tr>
<td>Y2</td>
<td>10.000000</td>
<td>INFINITY</td>
<td>INFINITY</td>
</tr>
<tr>
<td>Y3</td>
<td>10.000000</td>
<td>INFINITY</td>
<td>INFINITY</td>
</tr>
<tr>
<td>Y4</td>
<td>10.000000</td>
<td>INFINITY</td>
<td>INFINITY</td>
</tr>
<tr>
<td>Y5</td>
<td>10.000000</td>
<td>INFINITY</td>
<td>INFINITY</td>
</tr>
<tr>
<td>Y6</td>
<td>10.000000</td>
<td>INFINITY</td>
<td>INFINITY</td>
</tr>
<tr>
<td>Y7</td>
<td>10.000000</td>
<td>INFINITY</td>
<td>INFINITY</td>
</tr>
<tr>
<td>Y8</td>
<td>10.000000</td>
<td>INFINITY</td>
<td>INFINITY</td>
</tr>
<tr>
<td>Y9</td>
<td>10.000000</td>
<td>INFINITY</td>
<td>INFINITY</td>
</tr>
</tbody>
</table>

APPENDIX B
SAMPLE LINDO REPORT
APPENDIX C

ABBREVIATED LINDO SOLUTION REPORT,

FEE FOR SERVICE WITH NOV 85 DEMAND AND RESOURCES
APPENDIX C

\[ \text{MAX } 10 Y_1 + 43 Y_2 + 10 Y_3 + 43 Y_4 + 10 Y_5 + 76 Y_6 + 47 Y_7 + 43 Y_8 + 98 Y_9 \]

SUBJECT TO
1. \( Y_1 \geq 50 \)
2. \( Y_2 \geq 80 \)
3. \( Y_3 \geq 400 \)
4. \( Y_4 \geq 200 \)
5. \( Y_5 \geq 20 \)
6. \( Y_6 \geq 49 \)
7. \( Y_7 \geq 8 \)
8. \( Y_8 = 8 \)
9. \( Y_9 \geq 254 \)
10. \( Y_{10} \geq 5 \)
11. \( Y_{11} \leq 624 \)
12. \( Y_{12} \leq 292 \)
13. \( Y_{13} \leq 1020 \)
14. \( Y_{14} \leq 796 \)
15. \( Y_{15} \leq 288 \)
16. \( Y_{16} \leq 69 \)
17. \( Y_{17} \leq 13 \)
18. \( Y_{18} \leq 614 \)
19. \( Y_{19} \geq 5 \)
20. \( 15 Y_1 + 20 Y_2 + 10 Y_3 + 20 Y_4 + 15 Y_5 + 30 Y_6 + 20 Y_7 + 20 Y_8 + 30 Y_9 \leq 21853 \)

LP OPTIMUM FOUND AT STEP 14

OBJECTIVE FUNCTION VALUE
1) \( 42359.4500 \)

VARIABLE VALUE REDUCED COST
Y1 50.000000 .000000
Y2 262.150000 .000000
Y3 400.000000 .000000
Y4 200.000000 .000000
Y5 20.000000 .000000
Y6 69.000000 .000000
Y7 13.000000 .000000
Y8 254.000000 .000000
Y9 5.000000 .000000

NO. ITERATIONS= 14

DO RANGE(SENSITIVITY) ANALYSIS?

RANGES IN WHICH THE BASIS IS UNCHANGED:

<table>
<thead>
<tr>
<th>VARIABLE</th>
<th>OBJ COEFFICIENT RANGES</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CURRENT</td>
</tr>
<tr>
<td>Y1</td>
<td>10.000000</td>
</tr>
<tr>
<td>Y2</td>
<td>43.000000</td>
</tr>
<tr>
<td>Y3</td>
<td>10.000000</td>
</tr>
<tr>
<td>Y4</td>
<td>43.000000</td>
</tr>
<tr>
<td>Y5</td>
<td>10.000000</td>
</tr>
<tr>
<td>Y6</td>
<td>76.000000</td>
</tr>
<tr>
<td>Y7</td>
<td>87.000000</td>
</tr>
<tr>
<td>Y8</td>
<td>43.000000</td>
</tr>
<tr>
<td>Y9</td>
<td>98.000000</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ROW</th>
<th>CURRENT</th>
<th>ALLOWABLE RHS INCREASE</th>
<th>ALLOWABLE RHS DECREASE</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>50.000000</td>
<td>242.866700</td>
<td>39.800000</td>
</tr>
<tr>
<td>3</td>
<td>80.000000</td>
<td>182.150000</td>
<td>INFINITY</td>
</tr>
<tr>
<td>4</td>
<td>400.000000</td>
<td>364.300000</td>
<td>59.700000</td>
</tr>
<tr>
<td>5</td>
<td>200.000000</td>
<td>182.150000</td>
<td>29.850000</td>
</tr>
<tr>
<td>6</td>
<td>20.000000</td>
<td>242.866700</td>
<td>20.000000</td>
</tr>
</tbody>
</table>

--- More ---
| 7    | 49.000000 | 20.000000 | INFINITY |
| 8    | 8.000000 | 35.000000 | INFINITY |
| 9    | 254.000000 | 12.150000 | 7.950000 |
| 10   | 5.000000 | 0.000000 | INFINITY |
| 11   | 824.000000 | INFINITY | 172.000000 |
| 12   | 292.000000 | INFINITY | 33.850000 |
| 13   | 1020.000000 | INFINITY | 620.000000 |
| 14   | 796.000000 | INFINITY | 596.000000 |
| 15   | 288.000000 | INFINITY | 268.000000 |
| 16   | 69.000000 | 121.433300 | 19.900000 |
| 17   | 4.000000 | 132.150000 | 29.850000 |
| 18   | 614.000000 | INFINITY | 360.000000 |
| 19   | 5.000000 | 41.1300 | INFINITY |
| 20   | 21853.000000 | 597.300000 | 3641.300000 |
APPENDIX D

ABBREVIATED LINDO SOLUTION REPORT,

$100 HOURLY RATE, WITH NOV 85 DEMAND AND RESOURCES
APPENDIX D

\[
\text{MAX} \quad 25 \ Y_1 + 33 \ Y_2 + 17 \ Y_3 + 33 \ Y_4 + 25 \ Y_5 + 50 \ Y_6 + 33 \ Y_7 + 13 \ Y_9
\]

\[- 50 \ Y_9
\]

\text{SUBJECT TO}
\[
2) \quad Y_1 \geq 50
3) \quad Y_2 \geq 80
4) \quad Y_3 \geq 400
5) \quad Y_4 \geq 200
6) \quad Y_5 \geq 20
7) \quad Y_6 \geq 49
8) \quad Y_7 \geq 8
9) \quad Y_8 \geq 254
10) \quad Y_9 \geq 5
11) \quad Y_1 \leq 824
12) \quad Y_2 \leq 292
13) \quad Y_3 \leq 1020
14) \quad Y_4 \leq 736
15) \quad Y_5 \leq 288-
16) \quad Y_6 \leq 69
17) \quad Y_7 \leq 13
18) \quad Y_8 \leq 614
19) \quad Y_9 \leq 5
20) \quad 15 \ Y_1 + 20 \ Y_2 + 10 \ Y_3 + 20 \ Y_4 + 15 \ Y_5 + 50 \ Y_6 + 33 \ Y_7 + 13 \ Y_8
\]

\text{OBJ COEFFICIENT RANGES}

\begin{array}{llll}
\text{VARIABLE} & \text{CURRENT} & \text{ALLOWABLE} & \text{ALLOWABLE} \\
& \text{COEF} & \text{INCREASE} & \text{DECREASE} \\
Y_1 & 25.000000 & 0.500000 & \text{INFINTY} \\
Y_2 & 33.000000 & 1.000000 & \text{INFINTY} \\
Y_3 & 17.000000 & \text{INFINTY} & 0.333333 \\
Y_4 & 33.000000 & 1.000000 & \text{INFINTY} \\
Y_5 & 25.000000 & 0.500000 & \text{INFINTY} \\
Y_6 & 50.000000 & 1.000000 & \text{INFINTY} \\
Y_7 & 33.000000 & 1.000000 & \text{INFINTY} \\
Y_8 & 33.000000 & 1.000000 & \text{INFINTY} \\
Y_9 & 50.000000 & 1.000000 & \text{INFINTY}
\end{array}

\text{RIGHTHAND SIDE RANGES}

\begin{array}{llll}
\text{ROW} & \text{CURRENT} & \text{ALLOWABLE} & \text{ALLOWABLE} \\
& \text{RHS} & \text{INCREASE} & \text{DECREASE} \\
2 & 50.000000 & 289.533300 & 50.000000 \\
3 & 60.000000 & 212.000000 & 60.000000 \\
4 & 400.000000 & 434.300000 & \text{INFINTY} \\
5 & 200.000000 & 217.150000 & 92.850000 \\
6 & 20.000000 & 268.000000 & 20.000000 \\
7 & 49.000000 & 20.000000 & 49.000000 \\
8 & 8.000000 & 5.000000 & 8.000000 \\
9 & 254.000000 & 217.150000 & 92.850000 \\
10 & 5.000000 & 0.000000 & 5.000000 \\
11 & 624.000000 & \text{INFINTY} & 774.000000 \\
12 & 292.000000 & \text{INFINTY} & 212.000000 \\
13 & 1020.000000 & \text{INFINTY} & 366.700000 \\
14 & 796.000000 & \text{INFINTY} & 596.000000 \\
15 & 268.000000 & \text{INFINTY} & 268.000000 \\
16 & 69.000000 & \text{INFINTY} & 20.000000 \\
17 & 116.000000 & \text{INFINTY} & 9.000000 \\
18 & 614.000000 & \text{INFINTY} & 360.000000 \\
19 & 1.000000 & \text{INFINTY} & 0.000000 \\
20 & 21953.000000 & 21953.000000 & 21953.000000
\end{array}
APPENDIX E

ABBREVIATED LINDO SOLUTION REPORT, FLAT FEE,

WITH NOV 85 DEMAND AND RESOURCES
APPENDIX E

\begin{align*}
\text{MAX} & \quad 50.14 Y^1 - 50.14 Y^2 + 50.14 Y^3 + 50.14 Y^4 + 50.14 Y^5 + 50.14 Y^6 + 50.14 Y^7 + 50.14 Y^8 + 50.14 Y^9 \\
\text{SUBJECT TO} & \\
& Y^1 + Y^2 + Y^3 + Y^4 + Y^5 + Y^6 + Y^7 + Y^8 + Y^9 = 120 \\
& Y^1 \leq 50 \\
& Y^2 \leq 50 \\
& Y^3 \leq 400 \\
& Y^4 \leq 200 \\
& Y^5 \leq 20 \\
& Y^6 \leq 10 \\
& Y^7 \leq 8 \\
& Y^8 \leq 254 \\
& Y^9 \leq 5 \\
& Y^1 \geq 324 \\
& Y^2 \geq 292 \\
& Y^3 \geq 1020 \\
& Y^4 \geq 796 \\
& Y^5 \geq 358 \\
& Y^6 \geq 66 \\
& Y^7 \geq 13 \\
& Y^8 \geq 614 \\
& Y^9 \geq 5 \\
& 15 Y^1 + 20 Y^2 + 10 Y^3 - 20 Y^4 + 15 Y^5 + 10 Y^6 + 20 Y^7 + 20 Y^8 + 20 Y^9 \leq 21935 \\
\end{align*}

LP OPTIMUM FOUND AT STEP 3

OBJECTIVE FUNCTION VALUE

\begin{equation}
75134.7900
\end{equation}

\begin{tabular}{|l|c|c|}
\hline
\textbf{VARIABLE} & \textbf{VALUE} & \textbf{REDUCED COST} \\
\hline
Y^1 & 50.000000 & 0.000000 \\
Y^2 & 50.000000 & 0.000000 \\
Y^3 & 932.500000 & 0.000000 \\
Y^4 & 200.000000 & 0.000000 \\
Y^5 & 20.300000 & 0.000000 \\
Y^6 & 49.000000 & 0.000000 \\
Y^7 & 0.000000 & 0.000000 \\
Y^8 & 254.000000 & 0.000000 \\
Y^9 & 5.000000 & 0.000000 \\
\hline
\end{tabular}

\begin{equation}
\text{NO. ITERATIONS = 3}
\end{equation}

\begin{equation}
\text{DO RANGE(SENSITIVITY) ANALYSIS? Y}
\end{equation}

\begin{equation}
\text{RANGES IN WHICH THE BASIS IS UNCHANGED:}
\end{equation}

\begin{tabular}{|l|c|c|c|}
\hline
\textbf{VARIABLE} & \textbf{CURRENT ALLOWABLE} & \textbf{ALLOWABLE} \\
& \textbf{ALLOWABLE} & \textbf{ALLOWABLE} \\
& \textbf{COEF} & \textbf{INCREASE} & \textbf{DECREASE} \\
\hline
Y^1 & 50.140000 & 23.070000 & INFINITY \\
Y^2 & 50.140000 & 50.140000 & INFINITY \\
Y^3 & 50.140000 & INFINITY & .6713333 \\
Y^4 & 50.140000 & 50.140000 & INFINITY \\
Y^5 & 50.140000 & 25.070000 & INFINITY \\
Y^6 & 50.140000 & 100.280000 & INFINITY \\
Y^7 & 50.140000 & 50.140000 & INFINITY \\
Y^8 & 50.140000 & 254.000000 & INFINITY \\
Y^9 & 50.140000 & 5.000000 & 0.000000 \\
\hline
\end{tabular}

\begin{equation}
\text{RIGHT-HAND SIDE RANGES}
\end{equation}

\begin{tabular}{|l|c|c|c|}
\hline
\textbf{ROW} & \textbf{CURRENT ALLOWABLE} & \textbf{ALLOWABLE} \\
& \textbf{RHS} & \textbf{INCREASE} & \textbf{DECREASE} \\
\hline
2 & 50.000000 & 388.333300 & 50.000000 \\
3 & 90.000000 & 212.000000 & 90.000000 \\
4 & 450.000000 & 412.500000 & INFINITY \\
5 & 200.000000 & 216.000000 & 23.740000 \\
6 & 20.000000 & 288.000000 & 20.000000 \\
\hline
\end{tabular}

\begin{equation}
\text{NO. ITERATIONS = 3}
\end{equation}

\begin{equation}
\text{DO RANGE(SENSITIVITY) ANALYSIS? Y}
\end{equation}

\begin{equation}
\text{RANGES IN WHICH THE BASIS IS UNCHANGED:}
\end{equation}

\begin{tabular}{|l|c|c|c|}
\hline
\textbf{VARIABLE} & \textbf{CURRENT ALLOWABLE} & \textbf{ALLOWABLE} \\
& \textbf{ALLOWABLE} & \textbf{ALLOWABLE} \\
& \textbf{COEF} & \textbf{INCREASE} & \textbf{DECREASE} \\
\hline
Y^1 & 50.140000 & 23.070000 & INFINITY \\
Y^2 & 50.140000 & 50.140000 & INFINITY \\
Y^3 & 50.140000 & INFINITY & .6713333 \\
Y^4 & 50.140000 & 50.140000 & INFINITY \\
Y^5 & 50.140000 & 25.070000 & INFINITY \\
Y^6 & 50.140000 & 100.280000 & INFINITY \\
Y^7 & 50.140000 & 50.140000 & INFINITY \\
Y^8 & 50.140000 & 254.000000 & INFINITY \\
Y^9 & 50.140000 & 5.000000 & 0.000000 \\
\hline
\end{tabular}

\begin{equation}
\text{RIGHT-HAND SIDE RANGES}
\end{equation}

\begin{tabular}{|l|c|c|c|}
\hline
\textbf{ROW} & \textbf{CURRENT ALLOWABLE} & \textbf{ALLOWABLE} \\
& \textbf{RHS} & \textbf{INCREASE} & \textbf{DECREASE} \\
\hline
2 & 50.000000 & 388.333300 & 50.000000 \\
3 & 90.000000 & 212.000000 & 90.000000 \\
4 & 450.000000 & 412.500000 & INFINITY \\
5 & 200.000000 & 216.000000 & 23.740000 \\
6 & 20.000000 & 288.000000 & 20.000000 \\
\hline
\end{tabular}
APPENDIX F

ABBREVIATED LINDO SOLUTION REPORT, FEE FOR SERVICE,
WITH NOV 85 DEMAND AND SEP 85 STAFFING
APPENDIX F

MAX \[ 10 Y_1 + 43 Y_2 + 10 Y_3 + 43 Y_4 + 10 Y_5 + 76 Y_6 + 87 Y_7 + 43 Y_8 + 98 Y_9 \]

SUBJECT TO

1. \[ Y_1 \leq 50 \]
2. \[ Y_2 \leq 30 \]
3. \[ Y_3 \leq 60 \]
4. \[ Y_4 \leq 100 \]
5. \[ Y_5 \leq 20 \]
6. \[ Y_6 \leq 49 \]
7. \[ Y_7 \leq 8 \]
8. \[ Y_8 \leq 254 \]
9. \[ Y_9 \leq 5 \]
10. \[ Y_{10} \leq 924 \]
11. \[ Y_{11} = 924 \]
12. \[ Y_{12} = 286 \]
13. \[ Y_{13} = 320 \]
14. \[ Y_{14} \leq 796 \]
15. \[ Y_{15} \leq 288 \]
16. \[ Y_{16} \leq 69 \]
17. \[ Y_{17} \leq 13 \]
18. \[ Y_{18} \leq 614 \]
19. \[ Y_{19} \leq 5 \]
20. \[ Y_{20} \leq 47300 \]

LP OPTIMUM FOUND AT STEP 3

OBJECTIVE FUNCTION VALUE

1) 90481.0000

VARIABLE VALUE REDUCED COST

Y_1 50.000000 0.000000
Y_2 292.000000 0.000000
Y_3 973.000000 0.000000
Y_4 796.000000 0.000000
Y_5 20.000000 0.000000
Y_6 69.000000 0.000000
Y_7 13.000000 0.000000
Y_8 614.000000 0.000000
Y_9 5.000000 0.000000

NO. ITERATIONS = 3

DO RANGE (SENSITIVITY) ANALYSIS?

7

RANGES IN WHICH THE BASIS IS UNCHANGED:

OBJ COEFFICIENT RANGES

VARIABLE CURRENT ALLOWABLE ALLOWABLE
OBJ COEFF INCREASE DECREASE

Y_1 10.000000 INFINITY 23.000000
Y_2 43.000000 INFINITY 23.000000
Y_3 10.000000 11.500000 3.333333
Y_4 43.000000 INFINITY 23.000000
Y_5 10.000000 5.000000 46.000000
Y_6 76.000000 INFINITY 67.000000
Y_7 87.000000 INFINITY 67.000000
Y_8 43.000000 INFINITY 23.000000
Y_9 98.000000 INFINITY 68.000000

RIGHTHAND SIDE RANGES

ROW CURRENT ALLOWABLE ALLOWABLE
RHS INCREASE DECREASE

2 50.000000 302.000000 31.333333
3 80.000000 212.000000 INFINITY
4 400.000000 573.000000 INFINITY
5 200.000000 596.000000 INFINITY
6 20.000000 268.000000 20.000000

--- More ---

7 49.000000 20.000000 INFINITY
8 8.000000 5.000000 INFINITY
9 254.000000 360.000000 INFINITY
10 9.000000 5.000000 INFINITY
11 924.000000 INFINITY 174.000000
12 292.000000 286.500000 23.500000
13 1023.200000 INFINITY 47.000000
14 296.000000 286.500000 23.500000
15 288.000000 INFINITY 268.000000
16 59.000000 191.000000 15.500000
17 4.000000 296.500000 23.000000
18 5.000000 191.000000 15.500000
19 4.000000 296.500000 23.000000
20 20.000000 268.000000 20.000000

--- More ---
APPENDIX G

ABBREVIATED LINDO SOLUTION REPORT, $100 HOURLY RATE,

WITH NOV 85 DEMAND AND SEP 85 STAFFING
APPENDIX G

\[
\text{MAX} \quad 25Y_1 + 33Y_2 + 17Y_3 + 33Y_4 + 25Y_5 + 50Y_6 + 73Y_7 + 11Y_8 \\
+ 10Y_9 \\
\text{SUBJECT TO} \\
2) Y_1 \geq 50 \\
3) Y_2 \leq 80 \\
4) Y_3 \leq 400 \\
5) Y_4 \geq 200 \\
6) Y_5 \leq 20 \\
7) Y_6 \geq 49 \\
8) Y_7 \leq 8 \\
9) Y_8 \geq 254 \\
10) Y_9 \leq 5 \\
11) Y_1 = 824 \\
12) Y_2 = 292 \\
13) Y_3 = 520 \\
14) Y_4 = 736 \\
15) Y_5 = 238 \\
16) Y_6 \geq 69 \\
17) Y_7 \leq 73 \\
18) Y_8 = 614 \\
19) Y_9 \leq 5 \\
20) 15Y_1 + 20Y_2 + 10Y_3 + 20Y_4 + 15Y_5 + 30Y_6 + 20Y_7 + 20Y_8 \\
+ 30Y_9 \leq 47300 \\
\]

LP OPTIMUM FOUND AT STEP 7

OBJECTIVE FUNCTION VALUE

1) 78870.0000

VARIABLE VALUE REDUCED COST
Y1 924.000000 0.000000
Y2 60.000000 0.000000
Y3 1020.000000 0.000000
Y4 203.000000 0.000000
Y5 738.000000 0.000000
Y6 69.000000 0.000000
Y7 13.000000 0.000000
Y8 614.000000 0.000000
Y9 5.000000 0.000000

NO. ITERATIONS= 7

DO RANGE(SENSITIVITY) ANALYSIS?

RANGES IN WHICH THE BASIS IS UNCHANGED:

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<th>ALLOWABLE INCREASE</th>
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</tr>
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<td>Y5</td>
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<td>250000</td>
</tr>
<tr>
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</tr>
<tr>
<td>Y9</td>
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RIGHTHAND SIDE RANGES

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<td>4</td>
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</tr>
<tr>
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<td>4.000000</td>
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<tr>
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<td>774.000000</td>
<td>4.000000</td>
<td>774.000000</td>
</tr>
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</table>
APPENDIX H

ABBREVIATED LINDO SOLUTION REPORT, FLAT FEE,

WITH NOV 85 DEMAND AND SEP 85 STAFFING
APPENDIX H

\[
\begin{align*}
\text{MAX} & \quad 50.14 Y_1 + 50.14 Y_2 + 50.14 Y_3 + 50.14 Y_4 + 50.14 Y_5 + 50.14 Y_6 + 50.14 Y_7 + 50.14 Y_8 + 50.14 Y_9 \\
\text{SUBJECT TO} & \quad \begin{align*}
Y_1 & \leq 50 \\
Y_2 & \leq 80 \\
Y_3 & \geq 400 \\
Y_4 & \geq 400 \\
Y_5 & \geq 20 \\
Y_6 & \geq 49 \\
Y_7 & \leq 8 \\
Y_8 & \leq 284 \\
Y_9 & \geq 5 \\
Y_1 & \leq 824 \\
Y_2 & \leq 292 \\
Y_3 & \leq 1020 \\
Y_4 & \leq 796 \\
Y_5 & \leq 288 \\
Y_6 & \leq 69 \\
Y_7 & \leq 13 \\
Y_8 & \leq 614 \\
Y_9 & \leq 5 \\
15 Y_1 & + 20 Y_2 + 10 Y_3 + 20 Y_4 + 15 Y_5 + 30 Y_5 + 20 Y_7 + 20 Y_8 + 30 Y_9 & \leq 47300 \\
\end{align*}
\end{align*}
\]

LP optimum found at step 5

OBJECTIVE FUNCTION VALUE
1) \(56737.700\)

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<th>VALUE</th>
<th>REDUCED COST</th>
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<tr>
<td>Y1</td>
<td>324.000000</td>
<td>(0.000000)</td>
</tr>
<tr>
<td>Y2</td>
<td>80.000000</td>
<td>(0.000000)</td>
</tr>
<tr>
<td>Y3</td>
<td>1326.000000</td>
<td>(0.000000)</td>
</tr>
<tr>
<td>Y4</td>
<td>233.000000</td>
<td>(0.000000)</td>
</tr>
<tr>
<td>Y5</td>
<td>288.000000</td>
<td>(0.000000)</td>
</tr>
<tr>
<td>Y6</td>
<td>49.000000</td>
<td>(0.000000)</td>
</tr>
<tr>
<td>Y7</td>
<td>30.000000</td>
<td>(0.000000)</td>
</tr>
<tr>
<td>Y8</td>
<td>614.000000</td>
<td>(0.000000)</td>
</tr>
<tr>
<td>Y9</td>
<td>5.333333</td>
<td>(0.000000)</td>
</tr>
</tbody>
</table>

DO RANGE (SENSITIVITY) ANALYSIS?

RANGES IN WHICH THE BASIS IS UNCHANGED:

| VARIABLE | CURRENT ALLOWABLE ALLOWABLE COEF INCREASE DECREASE |
|----------|----------|----------|----------|----------|
| Y1       | 50.140000 | INFINITY  | 12.535000 |
| Y2       | 50.140000 | INFINITY  | 25.070000 |
| Y3       | 50.140000 | INFINITY  | 12.535000 |
| Y4       | 50.140000 | INFINITY  | 25.070000 |
| Y5       | 50.140000 | INFINITY  | 0.000000  |
| Y6       | 50.140000 | INFINITY  | 0.000000  |
| Y7       | 50.140000 | INFINITY  | 0.000000  |
| Y8       | 50.140000 | INFINITY  | 0.000000  |
| Y9       | 50.140000 | INFINITY  | 0.000000  |

RIGHTHAND SIDE RANGES

| ROW | CURRENT ALLOWABLE ALLOWABLE GHS INCREASE DECREASE |
|-----|----------|----------|----------|----------|
| 2   | 50.000000 | 774.000000 | INFINITY |
| 3   | 10.000000 | 33.000000  | 30.000000 |
| 4   | 400.000000 | 670.000000 | INFINITY |
| 5   | 50.000000 | 143.200000 | 10.000000 |
| 6   | 23.000000 | 268.000000 | INFINITY |

\[15 Y_1 + 20 Y_2 + 10 Y_3 + 20 Y_4 + 15 Y_5 + 30 Y_5 + 20 Y_7 + 20 Y_8 + 30 Y_9 \leq 47300\]
APPENDIX I

ABBREVIATED LINDO SOLUTION REPORT, FEE FOR SERVICE,

WITH NOV 85 DEMAND, NOV 85 STAFFING AND TWO FTE'S
### APPENDIX I

Maximize: \[ 51 Y_1 + 43 Y_2 + 10 Y_3 + 41 Y_4 + 10 Y_5 + 18 Y_6 + 47 Y_7 + 43 Y_8 + 93 Y_9 \]

Subject to:

1. \( Y_1 \leq 50 \)
2. \( Y_2 \geq 50 \)
3. \( Y_3 = 400 \)
4. \( Y_1 = 200 \)
5. \( Y_5 \geq 20 \)
6. \( Y_6 = 43 \)
7. \( Y_7 = 8 \)
8. \( Y_8 = 5 \)
9. \( Y_9 = 98 \)
10. \( Y_1 \geq 10 \)
11. \( Y_2 \leq 124 \)
12. \( Y_2 = 292 \)
13. \( Y_3 = 1020 \)
14. \( Y_4 = 756 \)
15. \( Y_5 = 288 \)
16. \( Y_6 = 69 \)
17. \( Y_7 = 13 \)
18. \( Y_8 = 614 \)
19. \( Y_9 = 5 \)
20. \( 15 Y_1 + 2 Y_2 + 10 Y_3 + 20 Y_4 + 15 Y_5 + 30 Y_6 + 20 Y_7 + 20 Y_8 + 30 Y_9 = 39133 \)

LP optimum found at step 15

<table>
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<tbody>
<tr>
<td>1) 79511.4500</td>
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<table>
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<th>VARIABLE</th>
<th>VALUE</th>
<th>REDUCED COST</th>
</tr>
</thead>
<tbody>
<tr>
<td>Y1</td>
<td>50.000000</td>
<td>0.000000</td>
</tr>
<tr>
<td>Y2</td>
<td>292.000000</td>
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<td>Y3</td>
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<td>Y4</td>
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<tr>
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No. iterations = 15

Do range (sensitivity) analysis?

Ranges in which the basis is unchanged:

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<th>ALLOWABLE DECREASE</th>
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<tbody>
<tr>
<td>Y1</td>
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<tr>
<td>Y2</td>
<td>43.000000</td>
<td>11.500000</td>
<td>INFINITY</td>
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<tr>
<td>Y3</td>
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<td>INFINITY</td>
</tr>
<tr>
<td>Y4</td>
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<td>23.000000</td>
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Righthand side ranges:

<table>
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APPENDIX J

ABBREVIATED LINDO SOLUTION REPORT, FLAT FEE,

WITH NOV 85 DEMAND, NOV 85 STAFFING AND TWO FTE'S
APPENDIX J

\[ \text{MAX} \quad 25 \, Y1 + 33 \, Y2 + 17 \, Y3 + 33 \, Y4 + 25 \, Y5 + 50 \, Y6 + 33 \, Y7 + 33 \, Y8 + 50 \, Y9 \]

\text{SUBJECT TO}

1) \quad Y1 >= 50
2) \quad Y1 >= 30
3) \quad Y2 >= 400
4) \quad Y3 >= 200
5) \quad Y5 >= 20
6) \quad Y6 >= 49
7) \quad Y7 >= 8
8) \quad Y8 >= 254
9) \quad Y9 >= 5
10) \quad Y1 <= 224
11) \quad Y2 <= 292
12) \quad Y3 <= 1020
13) \quad Y4 <= 786
14) \quad Y5 <= 288
15) \quad Y6 <= 69
16) \quad Y7 <= 13
17) \quad Y8 <= 614
18) \quad Y9 <= 5
19) \quad 15 \, Y1 + 20 \, Y2 + 10 \, Y3 + 20 \, Y4 + 15 \, Y5 + 33 \, Y6 + 20 \, Y7 + 20 \, Y8 + 30 \, Y9 <= 39133

LP OPTIMUM FOUND AT STEP 3

OBJECTIVE FUNCTION VALUE
1) \quad 65331.0000

<table>
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<th>VALUE</th>
<th>REDUCED COST</th>
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NO. ITERATIONS = 3

DO RANGE(SENSITIVITY) ANALYSIS? Y

RANGES IN WHICH THE BASIS IS UNCHANGED:

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<td>33.000000</td>
<td>.333332</td>
<td>INFINITY</td>
</tr>
<tr>
<td>Y9</td>
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<td>.0000000</td>
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RIGHTHAND SIDE RANGES

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--- More ---

|       | 49.000000   | 20.000000         | INFINITY           |
| 11    | 6.300000    | 5.000000          | 40.150000          |
| 12    | 500.000000  | 160.650000        | 43.150000          |
| 13    | 5.000000    | 0.000000          | INFINITY           |
| 14    | 124.000000  | 114.200000        | 81.150000          |
| 15    | 272.000000  | 160.900000        | 120.150000         |
| 16    | 199.000000  | 189.200000        | 130.150000         |
| 17    | 59.000000   | 46.200000         | 100.150000         |
| 18    | 385.200000  | 375.400000        | 90.150000          |
| 19    | 114.200000  | 104.400000        | 70.150000          |
| 20    | 64.000000   | 54.200000         | 60.150000          |
| 21    | 84.000000   | 74.200000         | 50.150000          |
| 22    | 124.000000  | 114.200000        | 81.150000          |
| 23    | 64.000000   | 54.200000         | 60.150000          |
| 24    | 124.000000  | 114.200000        | 81.150000          |
| 25    | 84.000000   | 74.200000         | 60.150000          |
APPENDIX K

ABBREVIATED LINDO SOLUTION REPORT, FLAT FEE,
WITH NOV 85 DEMAND, NOV 85 STAFFING AND TWO FTE'S
APPENDIX K

\[
\text{MAX} \quad 50.14 Y_1 + 50.14 Y_2 + 50.14 Y_3 + 50.14 Y_4 + 50.14 Y_5 + 50.14 Y_6 \\
+ 50.14 Y_7 + 50.14 Y_8 + 50.14 Y_9
\]

\[
\text{SUBJECT TO} \\
\begin{align*}
Y_1 & = 50 \\
Y_2 & = 60 \\
Y_3 & = 400 \\
Y_4 & = 200 \\
Y_5 & = 20 \\
Y_6 & = 69 \\
Y_7 & = 3 \\
Y_8 & = 254 \\
Y_9 & = 5 \\
\end{align*}
\]

LP OPTIMUM FOUND AT STEP 1

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<th>REDUCED COST</th>
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<tr>
<td>Y2</td>
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<td>Y3</td>
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<td>Y4</td>
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NO. ITERATIONS = 1

DO RANGE (SENSITIVITY) ANALYSIS?

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RIGHHAND SIDE RANGES

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<th>ROW</th>
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BIBLIOGRAPHY


