From Theory to Practice – Developing Decision Support Tools to Manage Cost and Quality of Obstetrical Care*

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This paper presents three simulation model applications to define resource requirements for inpatient obstetrical, neonatal intensive care unit (NICU) and obstetrical clinic services. The models define the effect changes in patient volume, clinical practices and administrative policies have on facility size and nurse staffing requirements. Linking clinical practice with capacity resources, the models help define the cost-quality relationship inherent in the delivery of health care services.

Why are new decision tools needed to improve performance in Managing Care?

Many hospitals are in financial stress. While competitive market forces continue to place downward pressure on revenues, effective cost control has remained elusive. Why are costs so difficult to control?

Healthcare providers do not look at their total production function the same way as other industries do. Healthcare providers focus on managing individual departments rather than on the cost-effectiveness with which the products of individual departments can be combined to produce patient care. The potential for changes in management of disease to affect the bottom-line is not well understood.

A key barrier preventing effective cost control is the masquerading of accounting tools as decision support tools. Accounting tools sum department costs and patient volume to determine average cost per patient day, per procedure, or per weighted work unit. These data are frequently used to make management decisions regarding relative efficiencies of operation.

Using departmental costs as the foundation for managing a health care delivery system creates two major problems. First, rather than exploring the efficient frontier, subsequent analyses must be based on averages. Second, process improvement is difficult to manage because the underlying causes for variation cannot be easily identified.

With accounting tools, analyses rest on average costs. But such analyses are unpersuasive if not accompanied by tools to support the reallocation of resources required to realize the cost savings.

Cost savings depend on reducing the volume of resources consumed in the treatment process – either resources consumed in an individual care episode (e.g., reducing length of stay) and/or reducing the volume of episodes (e.g., reducing admission or visit rates). Unfortunately, most resources are fixed in capacity investments (e.g., buildings, equipment, and staff). Consequently, a reduction in inputs does not automatically trigger a cost reduction. The cost savings can only materialize if the health care "production function" can be actively managed to reduce capacity resources in response to volume changes.

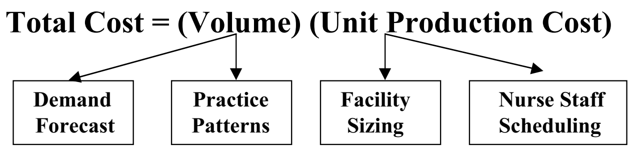
We believe standard operations research tools such as simulation modeling and linear programming can be used to make fixed operating costs more variable. True cost savings can only be achieved when the service line production function, the combination of patient care requirements and hospital resources, are frequently monitored and balanced. Hospital managers with these decision support tools can actively manage the service line production function and achieve significant operating cost savings.

Understanding the Treatment Process "Production Function"

Health care costs are a function of clinical volume and unit cost of the various health care services consumed in the treatment process. Clinical volume depends on patient demand and provider practice decisions. Unit cost depends largely on the investment in fixed capacity. Attempts to reduce health costs by concentrating only on reducing volume, while ignoring the challenge of managing fixed

* Paper Presented at 11TH Annual Quest for Quality & Productivity in Health Services Conference sponsored by the Society for Health Systems of the Institute of Industrial Engineers, 1999. Washington D.C.

capacity, will fall short since over eighty percent of total costs are locked in fixed investments for buildings, equipment, and staff. If fixed capacity is left unchanged, any reduction in volume will be offset by increases in unit cost leaving total costs relatively unchanged. Cost reduction depends on a simultaneous management of volume and unit cost. A brief description of the health care production function components for maternal and newborn infant services is discussed below.



Demand Forecasting

An accurate demand forecast provides the foundation for developing the decision tools necessary to manage the treatment process production function. The demand forecast must be based on the epidemiology of the population linked with the ability of the patient to access the care delivery system. An accurate demand forecast is extremely important. If the demand forecast is incorrect, then the delivery system's capacity resources will be incorrect – either too large or too small.

The forecast of the number of mothers giving birth is the foundation for managing maternal and child services. Exploring the relationship between patient demographics and fertility rates, the inpatient obstetrical volume forecast is zip code specific. Various independent variables, such as age, marital status, race, etc., are important in developing an accurate forecast. However, because fertility rates vary so significantly by age, single year age of the female population turns out to be the most important predictor variable. Once a woman is identified as pregnant, the outpatient forecast is a simple extrapolation of the inpatient forecast because the number and timing of pre and post-natal visits are well understood. The NICU volume forecast depends on the number of babies, not the number of pregnant women, in the population. Therefore, the obstetrical forecast is adjusted for the number of stillbirths and multiple births to develop the pool of infants with the potential to be admitted to a NICU.

The inpatient and outpatient obstetrical forecasts are very accurate because there is little inappropriateness in the admission and visit rates. The NICU forecast is more problematic because the appropriateness of the admission, especially for infants over 2,500 grams without complications, can be questioned in many cases. Therefore, provider practice patterns are an important factor in the accuracy of the NICU forecast, while relatively unimportant for the obstetrical forecasts.

Practice Pattern Analysis

Clinical practice decisions translate patient demand into workload (e.g., inpatient days and outpatient visits). The challenge is to understand the relationship between workload and patient outcome. Variation in clinical practice has significant impact on capacity resource requirements. Historical clinical practice patterns must be analyzed to explore the cost and quality ramifications of resource intensive practice patterns such as cesarean delivery rates, non-delivered obstetrical admission rates and average length of stay parameters. By modeling the production function, practice pattern decisions can be linked to facility square footage, equipment, and support staff requirements. In our opinion, unless the decision support tools can account for appropriateness of clinical practice variation, the outcome of decision tools can be unsatisfactory because of the "clinical noise" in the delivery system.

Facility Sizing

Based on the results of practice pattern analyses, operations research techniques (e.g., Poisson Process) are used to model the number of facilities needed in a region and the size of each facility. When either expanding or realigning capacity, construction costs of an obstetrical bed average around $300,000. Therefore, the sizing decisions can have important cost ramifications. Rather than a "black box", the sizing models are built interactively with clinical and administrative staff involvement. Many times the interactive process provides as much value as the final model, in large part by helping to build consensus. The interactive nature of the modeling process gives the medical, marketing, fiscal, and administrative staff a common way of exploring the options available and understanding the cost and quality impact on the facility or network.

Staff Scheduling

Staff expenses add, at the minimum, 65 percent to total operating costs. The efficiency with which the staff is scheduled to match the acuity needs of the patients is a significant factor in determining total cost.

Using optimization techniques, monthly nurse staff schedules are produced. This approach has an advantage over more traditional methods of scheduling staff because, rather than using average staff requirements by shift, the schedules are based on hourly labor requirements. While the time a specific patient will arrive at a facility is largely a random process, the distribution of the number of patients who will arrive at a specific time can be predicted quite accurately. Using historic institutional data on how patients proceed through the stages of labor, hourly support staff requirements are predicted.

Most inpatient support personnel schedules employ a constant core staff in standard shifts of all eight or all 12-

hour employees with constant start and stop times. Significant staff savings can be achieved if the schedules can be made responsive to changes in demand (mixed eight, 10 and 12 hour personnel with staggered start times for each day of the week). Depending on an institution's scheduling practice, staff support savings on the order of 10 to 30 percent can be achieved.

Power of Simulation Modeling

Understanding the components of the health care production function, a coordinated cost control strategy can be developed. However, without the added power of simulation modeling, these strategies suffer a serious flaw.

Using the delivery of obstetrical services as an example, assume a detailed analysis of the four cost components has been completed. An accurate birth volume forecast has been developed based on female population demographics and fertility rates. The important obstetrical practice patterns have been analyzed (e.g., vaginal birth ALOS, cesarean delivery rate, etc.) and clinical targets have been established by the medical staff. The inpatient unit has been sized using probabilistic models (e.g., Poisson Process). Using optimization techniques, nurse staff schedules have been prepared based on patient acuity needs and staffing policies.

While the resulting nurse staff schedule is a significant achievement over more traditional approaches because it links nurse staff requirements and physical capacity with clinical practice patterns and patient demand, an extremely important dimension is missing from this solution!

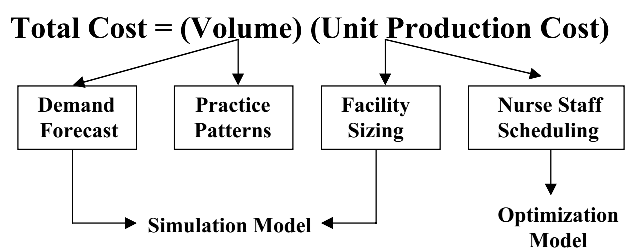
The problem is the data on which these analyses are based are at least a year old. The level of capacity resources (e.g., facility size, equipment, and staff) derived from these analyses are based on what occurred a year or more ago. Things may have changed. For example, patient volume may have increased or decreased due to enrollment or population shifts. Clinical practice patterns may have changed due to shift in the provider mix or new evidence concerning the quality of outcomes. Competitive pressures may force a move away from LDRs to LDRPs. A union may have been successful in organizing the nursing staff.

Once a simulation model has been constructed and validated using historical data, the model is a powerful tool to explore the consequences of changes in parameters. The health care production function is a dynamic rather than a static process. The key to managing total costs is the simultaneous management of these four cost components. Simulation models have been designed to mimic the actual flow of patients through an inpatient and an outpatient unit as closely as possible. By modeling the patient care paths, the relationship among patient volume, clinic practice, facility size, and staffing can be fully explored.

Presentation of Decision Support Tools for Obstetrics

Inpatient Obstetrical and NICU Services

The challenge in managing the cost of obstetrical and NICU services is matching the need for patient services with appropriate capacity resources when faced with the random nature of patient arrivals to the inpatient unit. Except for scheduled procedures, the exact time of patient arrival is uncertain. Without a sophisticated method of managing uncertainty, it is common to compensate by over-building and over-staffing. Simulation coupled with optimization models is uniquely suited to analyze the effect on performance from random events. Therefore, these models are the perfect tool to help clients manage the delivery of obstetrical and NICU services.



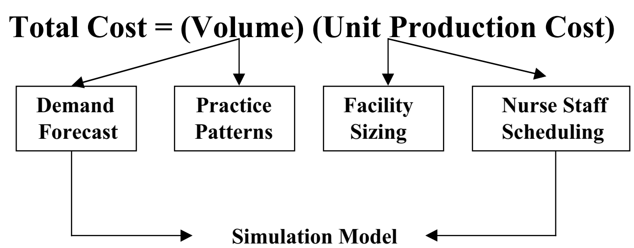
In the inpatient setting, the capacity levels in the simulation model are unconstrained and staff and room utilization are tracked based on patient acuity requirements. A woman in active labor or an infant with respiratory difficulties does not wait for a bed or a respirator to become available. In order to accurately measure the requirement for capacity resources, the model assumes resources are unlimited. Constraints are introduced in the facility sizing analysis and in determining the staffing policies for flexibility (e.g., degrees of freedom) in determining short-term augmentation and rotating scheduling policies.

The simulation model output defines the distribution of workload or nursing staffing requirements. The optimization model determines the staff schedule needed to satisfy the nurse staff requirements based on scheduling rules. Using the two decision models interactively, the client is able to re-engineer the nurse staff requirement through changes in patient volume, clinical practice or facility size (e.g., simulation model) or improve scheduling flexibility by relaxing scheduling rules (e.g., optimization model) to define the most efficient treatment process production function.

Outpatient Obstetrical Services

The challenge in managing an outpatient clinic is similar to an inpatient setting in the sense that resources must be matched with patient need. However, there are differences. In an outpatient clinic, the majority of patient arrivals are not random, but known in advance. In addition, the clinic does not operate 24 hours a day, but empties out each evening.

Most important, the outpatient model is constrained. Unlike in the inpatient setting, outpatients can wait if resources are not available. For example, if the room or the provider is occupied with other patients, then the next patient waits until the constrained resource is available. With constraints included in the model, a simulation technique can model all four components of the production function.



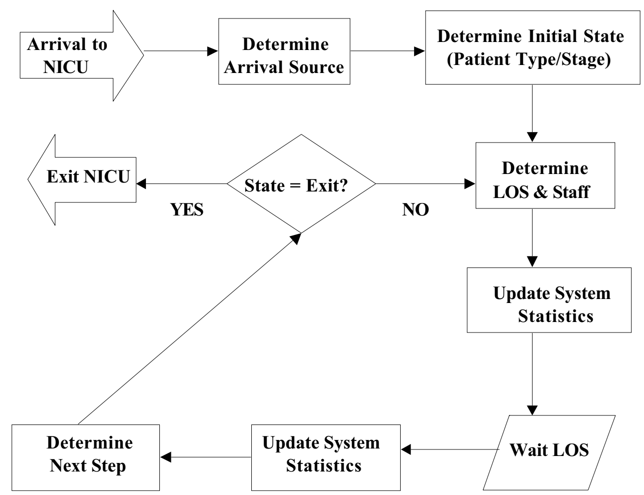
Discrete event simulation modeling is a powerful approach for analyzing complex service systems such as those found in outpatient clinics. Simulation analysis can often reveal important relationships between independent variables such as capacity (e.g. number of exam rooms, number of providers, and support staff levels), or demand and important system performance measures such as customer wait time or capacity utilization. Important features of clinic systems such as time of day and day of week effects, complex patient routing, appointment based arrivals and stochastic service times can be modeled without great difficulty.

Overview of Model Logic

Inpatient and NICU Models

Patients arrive according to a patient type specific non-homogeneous Poisson process. Upon arrival they enter one of three arrival source states – obstetrical unit, surgery, or transfer from another facility. They immediately transition to their first patient care state based on a transition probability matrix. Also, in the case of the NICU, random sampling is used to determine if the patient requires any special resources such as a ventilator. The patient remains in that state for a random amount of time based on a state specific length of stay distribution. After the sampled length of stay expires, the patient makes a transition to a new state based on the transition probability matrix. If the next state is one of the defined departure states, the patient exits the system. Otherwise the patient samples from the appropriate length of stay distribution and begins their next state occupation. This sequence repeats until the patient exits the system. It is assumed that the state transition probabilities have been specified in such a way that there is a positive probability that each patient eventually exits the system. Whenever a patient enters a new state, several arrays are updated which track both census and nurse staffing needs by state, bed level, and overall. The model logic for the NICU model is presented above.

Overview of Model Logic



Outpatient Model

The purpose of the obstetrical clinic model (OCM) is to provide a means of addressing a number of capacity planning and operational questions related to outpatient clinics. A high level representation of the architecture of the model is displayed below. Conceptually, the outpatient clinic model can be viewed as three related sub-models:

- Demand Generation
- Appointment Scheduling
- Clinic Operations

Demand Generation

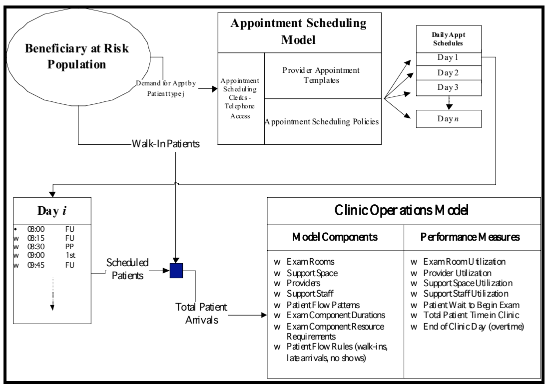
Demand generation involves both demand for clinic appointments and acute care "walk-in" visits and is related to the needs of the underlying service area population. Demand is sub-classified into a small number of distinct patient types and the magnitude and time of day patterns of these distinct arrival streams are represented in the model.

Appointment Scheduling

Appointment scheduling refers to appointment templates, provider staffing and the procedures by which appointment slots are allocated to meet patient demand. This component is critical to clinic performance as it essentially specifies total capacity and thus affects clinic congestion and access to the clinic.

Clinic Operations

The clinic operations sub-model refers to the actual events that occur during the course of a patient's visit to the clinic. This includes the areas visited within the clinic and the duration of time spent with various providers and support staff.



Application of the Decision Support Tools

Ideally, the three sets of decision support tools (e.g., inpatient obstetrics, NICU, and outpatient obstetrical clinic) should be used in conjunction to help design a regional solution for the delivery of obstetrical services. The capacity of the inpatient units, ambulatory clinics and NICU should be balanced with the expected patient volume and provider practice patterns in order to develop the best cost and quality solution for the regional delivery of obstetrical services. Unfortunately, the opportunity has not presented itself to apply all three sets of tools in the same region. Therefore, the applications of the tools are addressed singularly.

Inpatient Obstetrics

The decision support tools have been successfully implemented in six inpatient facilities. There are four facilities in the process of implementation. Approximately, three million dollars in annual savings have been identified at each facility. The savings are a result of a reduction in staff with a constant patient volume, an increase in patient volume with the same staff or a combination of the two. In addition, the models have been useful in measuring the cost savings from switching between an LDR and LDRP room arrangement. In the one facility analyzed, twenty-five percent fewer nurses were required with the LDRP.

NICU

The NICU simulation model is in the process of implementation in one facility. However, difficulties in obtaining data for the institution’s automated system prevented the path branching and service time distributions to be calculated with actual data. Instead, “expert opinion” from the provider staff was used to populate the model. While these estimates allowed the model to be built and run, actual data is needed before nurse-staffing decisions can be based on the model’s output. We expect the data problems to be solved in the near future.

Outpatient Clinic

The clinic model has been implemented in one facility and is in the process of being implemented at another. With first implementation, data was not available to populate the patient clinic paths, therefore, no results can be reported. The additional data collection needed to define the branching probabilities and the service times of the paths is part of the contract for the second institution. These data are also being collected at the first implementation site. We expect to be able to report results at the end of September 99 for both sites.

Biographical Sketch

Timothy McKee is a principal with Health Services Engineering, Inc. which specializes in managing health care costs by using operations research tools to integrate clinical practice and capacity management. Prior to co-founding Health Services Engineering, he served as Executive Director, Program Review and Evaluation for the Assistant Secretary of Defense for Health Affairs where he was responsible for evaluating the delivery of health care services for the Department of Defense. He received his doctorate from the University of Michigan in Health Services Organization and Policy with a concentration in Industrial Engineering.

Timothy Ward is a principal with Health Services Engineering with extensive experience in applying analytical models to improve performance in over fifty hospitals throughout the United States. Prior to co-founding Health Services Engineering, he served as a senior analyst for the Assistant Secretary of Defense for Health Affairs where he concentrated on improving system performance regarding facility sizing and staffing. He is an ABD from the doctoral program at the University of Michigan in Health Services Organization and Policy. He received a Masters degree in Industrial and Operations Engineering from Michigan. He also has Masters degrees in general engineering and architecture from the University of Illinois. He is a member of SHS and HIMSS.

Mark Isken is an Assistant Professor, Department of Decision and Information Sciences, Oakland University and is a Senior Scientist with Health Services Engineering, Inc. He has extensive practice experience and accomplished research relating to improving hospital operations, especially in the areas of personnel scheduling models and simulation modeling. He received his doctorate from the University of Michigan in Industrial and Operations Engineering. He is a member of numerous professional societies including SHS, HIMSS, INFORMS, and POMS.