THE ASSISTANT SECRETARY OF DEFENSE
WASHINGTON, D C 20301-1200

HEALTH AFFAIRS

FEB 2 7 2004

The Honorable John W. Warner
Chairman, Committee on Armed Services
United States Senate
Washington, DC 20510-6050

Dear Mr. Chairman:

The enclosed report responds to Section 733 of the National Defense Authorization Act for Fiscal Year 2001 and Section 737 of the National Defense Authorization Act for Fiscal Year 2002, which directed the Department of Defense to implement a demonstration program on health care management for the purpose of exploring opportunities for improving the planning, programming, budget systems, and management of the Military Health System. The goals of the demonstration were (1) test the use of a health care simulation model for studying alternative delivery policies, processes, organizations, and technologies; and, (2) to test the use of a health care simulation model for studying long-term disease management

The modeling for TRICARE Region 11 tested alternative delivery policies, processes, organizations, and technologies. Simulation effectively examined the impact of: (1) a "circuit-rider" plan to augment specialty care, (2) increasing provider productivity resulting from local optimization initiatives, and, (3) a major medical deployment from a military treatment facility. The use of simulation for long-term disease management showed that it could predict how disease management could change Intensive Care Unit usage at Wilford Hall Medical Center in San Antonio, Texas.

This project demonstrated that simulation modeling is an important tool in strategic planning and operational decision making As indicated in the conclusion of the attached report, a centralized structure for MHS modeling and simulation is the next step to build upon the knowledge derived from the demonstration program

Thank you for your continued interest in the Military Health System

Sincerely,

William Winkenwerder Jr.

William Winkenwerder, Jr., MD

Enclosure:
As stated

cc
Senator Carl Levin

Health Care Management Demonstration
Report to Congress

(Section 733 of the National Defense Authorization Act for Fiscal Year 2001 and
Section 737 of the National Defense Authorization Act for Fiscal Year 2002)

Prepared by:

Office of the Assistant Secretary of Defense (Health Affairs)/
TRICARE Management Activity

Health Care Management Demonstration

TABLE OF CONTENTS

TABLE OF FIGURES

EXECUTIVE SUMMARY

The National Defense Authorization Act of 2001 and 2002 directed the Department of Defense (DoD) to explore management science tools to improve decision making in the Military Health System (MHS). The goal of the demonstration was to (1) test the use of a health care simulation model for studying alternative delivery policies, processes, organizations, and technologies; and (2) test the use of a health care simulation model for studying long-term disease management. Subsequently, the due-date of the demonstration program report was extended until March 15, 2004. This extension period has allowed the development and use of several additional simulation models and the exploration of innovative approaches to improve their utility for healthcare managers down to clinic level.

The demonstration of the use of simulation in managing alternative delivery policies, processes, organizations, and technologies (goal 1) was undertaken in Region 11, TRICARE Northwest, as part of the optimization effort in that region. The Region 11 study focused on three topics and their potential impact on the region's performance. The study topics examined the impact of: (1) a "circuit-rider" plan to augment specialty care at certain MTFs; (2) increasing provider productivity resulting from local optimization initiatives (e.g., centralized scheduling, increased ancillary support, etc.); and (3) a major medical deployment from one of the MTFs in the region. The results showed (1) that much of demand for specialty care (cardiology visits) would not be scheduled largely because of acuity levels, (2) that after 20% recapture of purchased care most of the increase in primary care productivity comes from family medicine, and (3) a three-month deployment would increase purchased care approximately $1.0 to $1.2 million. Since the purpose of the study was to explore the use of simulation modeling as a decision support tool, the questions were designed to examine various aspects of a region's operations. Investigation of these questions led to insights that supplemented other analytical efforts conducted to support Region 11 optimization.

The demonstration of the use of a health care simulation model for studying long-term disease management (goal 2) was conducted at Wilford Hall Medical Center (WHMC), San Antonio, Texas. This study, as part of a redesign effort at WHMC, examined the impact of adopting disease management practices on the future demand for the adult intensive care unit (ICU). As input to the design process, an estimate of future demand was needed, including an assessment of the extent to which demand might be reduced by adopting disease management practices. The results of this long-term disease management study showed that disease management programs for chronic obstructive pulmonary disease (COPD), heart failure, and diabetes are likely to reduce the demand for ICU beds. The quantitative analysis conducted in this study helped identify where to focus disease management efforts and helped to quantify the likely magnitude of the benefit. Such quantification is useful in the context of the ongoing plans to restructure and resize the existing ICU.

In a follow-on study, simulation of ICU operations at WHMC was successfully used to assist in planning for expansion of the ICU and to explore the effects of ICU size and operating policies on access to care, utilization levels, the ability of the ICU to support GME programs, and the ability to sustain ICU operations in the face of a major medical deployment.

A series of simulation models of clinic operations has been used to explore the effects of resource availability, patient volumes, and processing times on patient time spent in the system, and resultant patient satisfaction. These models have also been used to identify the resources required to support various patient volumes. Spreadsheets containing the outputs of systematic runs of some of these models have been developed to provide easy access to model results without having to rerun the models. The extensive analysis that led to these spreadsheets also generated insights into clinic operations.

Adequate decision support tools are vital to supporting the DoD's optimization efforts. The MHS has a long history of developing automated clinical systems to support the patient-provider interaction and accounting tools to support the budget process. While these transaction and reporting systems have important roles, they are limited in their ability to support the realization of cost-effectiveness goals and the management of constrained resources. The health care system is very gradually moving toward a model where organizational structures and tools from other industries are being adopted. As that occurs, management science tools such as simulation will become increasingly important. Simulation-based analyses offer the MHS the opportunity to address issues of supporting best practices, determining the trade-offs inherent in managing constraints, and analyzing the complexities of disease product lines. These tools are vital to supporting DoD optimization efforts.

INTRODUCTION

The 106th Congress, through enactment of the National Defense Authorization Act for fiscal year 2001, Section 733, directed the DoD to implement a demonstration program on health care management, exploring opportunities for improving the planning, programming, budget systems, and management of the Department of Defense health care system. Section 737 of the National Defense Authorization Act for Fiscal Year 2002 extended the reporting period to March 15, 2004. The goal of the demonstration was to (1) test the use of a health care simulation model for studying alternative delivery policies, processes, organizations, and technologies, and (2) test the use of a health care simulation model for studying long-term disease management. Subsequently, the due-date of the demonstration program report was extended until March 2004. With additional Congressional authorization through fiscal year 2003, this extension period has allowed the development and use of several additional simulation models and the exploration of innovative approaches to improve their utility for healthcare managers down to clinic level.

Simulation projects were conducted in several separate locations to assess the two goals and develop the additional models. Simulation-based analysis involves the development of a computer representation of the process of interest. It is an important capability because it allows decision-makers to anticipate future events and plan for these events accordingly. Simulation tools are frequently designed to represent the uncertainty that is inherent in many processes, and, as a result, gives the decision-maker a realistic view of the future.

The demonstration of the use of simulation in managing alternative delivery policies, processes, organizations, and technologies (goal 1) was undertaken in Region 11, TRICARE Northwest, as part of the optimization effort in that region. In September 2000, the DoD awarded a contract to Vector Research, Incorporated (VRI is now the Altarum Institute) to conduct this pilot simulation-based analysis. This project was completed during April 2001. The demonstration of the use of a health care simulation model for studying long-term disease management (goal 2) was conducted at Wilford Hall Medical Center, San Antonio, Texas. A contract was awarded to VRI in September 2001 and the project was completed during January 2002.

As a follow on to the disease management study a simulation study was conducted for the purpose of exploring various intensive care unit (ICU) sizing options and several alternative and conflicting management policies. A contract was awarded to the Altarum Institute in September 2002 and the study was completed in January 2003. Additionally, multiple contracts were awarded to Health Services Engineering, Inc. to continue development of their basic clinic model and to develop easy-to-use decision support tools from the model output.

BACKGROUND

The DoD health care system covers a service population that includes active duty members, retirees, and their respective family members – a population of about 8.1 million. The Department delivers health care through its system of almost 500 military treatment facilities (MTFs) worldwide. These facilities include medical centers that provide tertiary care as well as providing graduate medical education (GME), smaller community hospitals with less extensive service availability, and clinics offering outpatient services only. Pharmacy services are available at most MTFs and are free-of-charge at the MTF. Care provided at MTFs is augmented with care provided by networks of civilian providers who complement and supplement the direct care system. Regional managed care support contractors (MCSC) are responsible for network development, claims processing, and other support to the direct care system.

The TRICARE program is the Department's regional managed-care program. Those beneficiaries who choose to enroll in TRICARE have reduced out-of-pocket costs with a uniform benefit structure. At the direction of Congress, the TRICARE program is administered so that costs incurred by the DoD are no greater than would otherwise have been incurred under the traditional benefit of direct care and CHAMPUS.

The management of the direct care system is divided among the Office of the Secretary of Defense (Health Affairs) and the three Services, with each Service having direct responsibility for its own MTFs. The Assistant Secretary of Defense (Health Affairs) and a subordinate activity, the TRICARE Management Activity (TMA), coordinate the development of the Defense Health Program budget, health care policy, and the development and implementation of health care support contracts in each of the TRICARE regions. Policy execution is delegated to the TMA and is shared with the Surgeons General of the three Services. In each TRICARE region, a lead agent coordinates MTF and contractor services.

THE USE OF SIMULATION ANALYSIS WITHIN THE MHS

Prior to the implementation of the Region 11 simulation-based analysis directed by the National Defense Authorization Act, simulation was used in the following areas within the MHS:

- Simulation (SIM) 2020: In 1995, SIM 2020 was developed using a simulation tool that allowed the MHS to evaluate its population using various regional population subsets. This model was designed to help the MHS senior leadership develop a greater "what if" understanding of the relationships between populations and investments in areas such as population health initiatives and information management/technology.
- OB Simulation Models: At the clinic level, the Assistant Secretary of Defense (Health Affairs) and the Surgeon General of the Navy conducted simulation-based studies at several MTFs. During the 1996-2000 time period, these studies were designed to demonstrate the benefits of simulation analysis in helping define and manage resources for obstetrical services in the inpatient and outpatient settings. The studies were implemented using discrete-event simulation models to forecast the resource and capacity implications of varying clinical practices, scheduling practices, and facility design in delivering obstetrical care.
- Telemedicine studies: The Army, in concert with the private sector, developed a simulation model to forecast the performance of a network, or complex, of health care delivery facilities. This model also includes a telemedicine module that can explore the implications of implementing telemedicine capabilities within a health care network. The Army used this model to evaluate return-on-investment of worldwide telemedicine deployment and provide an understanding of the economic impact of a regional teledentistry implementation plan.
- Long-term Disease Management Studies: The Army and Air Force, in concert with the private sector, have developed a simulation tool to evaluate disease management programs for chronic diseases such as diabetics. The purpose of this tool is to provide a better understanding of the impact of disease management on workload and population health status.

These earlier studies clearly demonstrated that well-developed simulation-based modeling is a powerful decision support tool when combined with active clinical and administrative involvement at the MTF. At the MTF, simulation tools allowed managers to optimize performance given facility, staffing, and funding constraints they faced. At the Service level, simulation has the potential to assist in the allocation of resources and to provide an understanding of the resource implications of varying MTF practices.

THE REGION 11 PILOT ANALYSIS

During September 2000, the DoD contracted with VRI to explore the potential of simulation-based analysis for goal 1, as directed by the National Defense Authorization Act, in Region 11. Region 11 is also the demonstration site for the Department's optimization effort. MHS optimization has these underlying tenets:

- Effectively use readiness-required personnel and equipment to support the peacetime health service delivery mission
- Equitably align resources to provide as much health service delivery as possible in the most cost-effective manner – within the MTF
- Use the best, evidence-based clinical practices and a population health approach to ensure consistently superior quality of services

This plan requires that MTFs:

- Increase MTF workload as part of an effort to decrease the unit cost of providing medical services
- Increase capacity in the direct care system by increasing productivity
- Increase ease of access to services for the enrolled population
- Decrease demand for traditional health care services by managing the health of the enrolled population

Region 11 was chosen for the goal 1 simulation analysis because its leaders were actively searching for decision support tools to assist with the optimization plan. The study was designed to demonstrate the value of simulation when applied to a regional health care system. The ability of simulation to "look ahead" at various aspects of Region 11's business plan offered the potential to experiment with alternative plans without the time and expense of actual implementation. The look-ahead capability of simulation produced measures of performance of a modeled health care system under different configurations of facility networks, resource allocations, and demand for health services.

Simulation Study Topics

The Region 11 simulation study focused on three topics and their potential impact on the region's performance. The study topics examined the impact of: (1) a "circuit-rider" plan to augment specialty care at certain MTFs; (2) increasing provider productivity resulting from local optimization initiatives (e.g., centralized scheduling, increased ancillary support, etc.); and (3) a major medical deployment from one of the MTFs in the region. Since the purpose of the study was to explore the use of simulation modeling as a decision support tool, the questions were designed to look at various aspects of a region's operations.

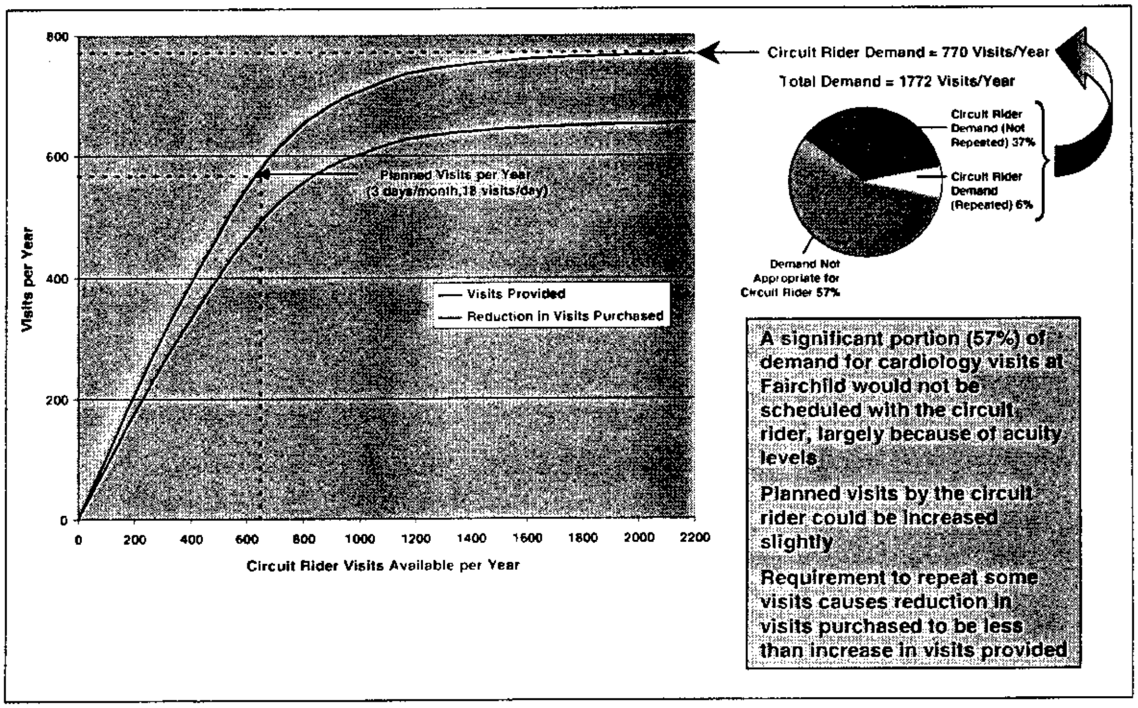
Regional performance, for the purposes of the study, was measured by:

- Workload (visits, admissions, and same-day surgeries) provided by Region 11 MTFs
- Workload purchased from the Managed Care Support Contractor
- Unused capacity for workload at Region 11 MTFs
- The number of enrollees in Region 11
- The magnitude of the Bid Price Adjustment
- Waiting times for MTF appointments

The Circuit Rider Program

A "circuit rider" program involves the use of traveling physicians who periodically visit outlying facilities to augment the capability of those facilities. The goal is to increase provider productivity by moving physicians to the point of patient demand. For example, Region 11's plan called for augmenting dermatology at Naval Hospital Oak Harbor and dermatology, cardiology, gastroenterology, and urology at the 92nd Medical Group at Fairchild Air Force Base using specialists from Madigan Army Medical Center.

Results of the analysis of the implementation of the cardiology circuit rider at Fairchild are illustrated as an example of the circuit rider analysis (Figure 1). The pie chart describes demand for cardiology visits at Fairchild, with the entire pie representing annual demand. Most of the cardiology demand for care is not appropriate for treatment by a circuit rider due to the urgent needs of the patient. A small but significant amount of care would likely be repeated by the ultimate treating physician upon a second referral from the circuit rider to a MCSC provider. Planned visits for the cardiology circuit rider could be increased slightly with greater availability of circuit rider visits. Adding equipment or ancillary personnel to the cardiology circuit rider would likely have negligible impact on workload capacity given the clinical risk.



A significant portion (57%) of demand for cardiology visits at Fairchild would not be scheduled with the circuit rider, largely because of acuity levels

Planned visits by the circuit rider could be increased slightly

Requirement to repeat some visits causes reduction in visits purchased to be less than increase in visits provided

FIGURE 1: SIMULATION ANALYSIS OF CARDIOLOGY CIRCUIT RIDER PLAN AT FAIRCHILD

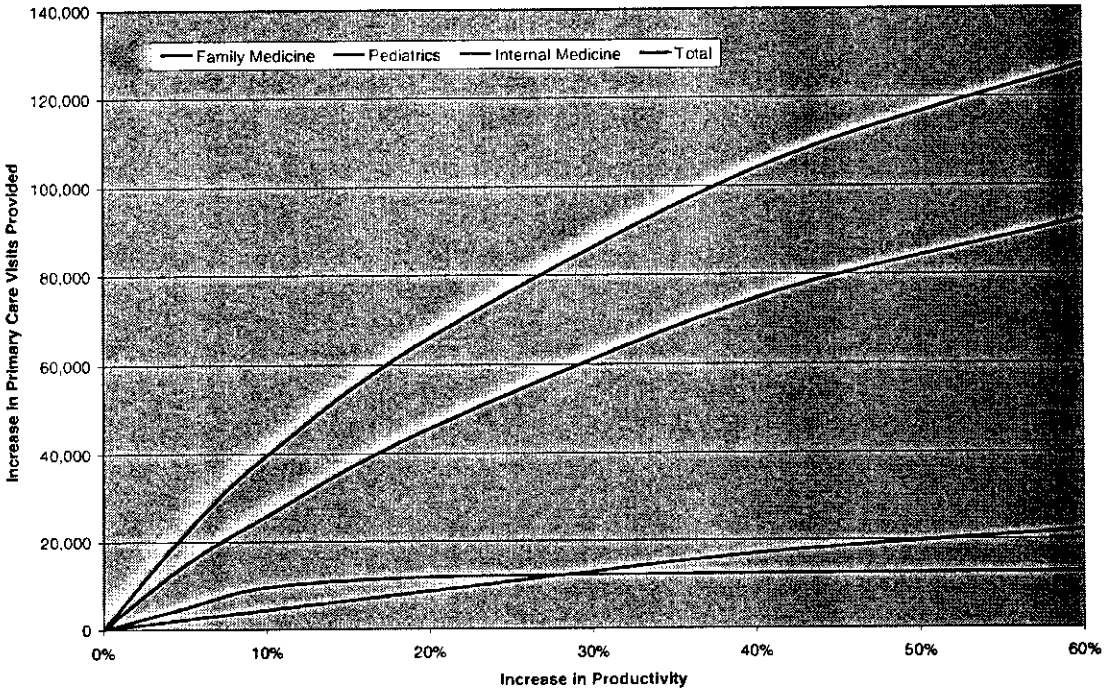
Simulation-based analysis allowed for a more robust analysis of the circuit rider initiatives in Region 11 than that which could be accomplished through a simple deterministic analysis. Simulation-based analysis represents the dynamics of the queuing process and the constraints that exist in the healthcare process allowing for the determination of a more nearly optimal operating point for each circuit rider initiative.

Provider Productivity Analysis

The Region 11 Business Plan presents a plan to implement a comprehensive population-health management capability. An important part of this effort focuses on primary care reengineering. This global initiative includes a number of interrelated proposals that are designed to yield productivity gains in the region's primary care clinics. These initiatives include addressing primary-care team efficiency, appointing process and template management, expanded roles of non-provider staff, and implementation of a prevention/disease monitoring process.

In this study, the provider productivity analysis focused on predicting the impacts of increasing the productivity of primary care providers in Region 11 as might be expected from the primary care reengineering initiative. In the context of this analysis, primary care was defined care provided in family practice, pediatric, and internal medicine clinics. An increase in primary care productivity of only 5 percent was examined at the two Air Force facilities (McChord AFB Clinic and Fairchild AFB Clinic) as these facilities have already undertaken significant reengineering activities. Increases in primary care productivity from 5 percent to 60 percent were deemed possible at Madigan AMC, NH Oak Harbor, and NH Bremerton.

The simulation study examined the impact of increased primary care productivity at the MTF and regional levels. The regional results are illustrated in Figure 2. This analysis illustrates that, as primary care productivity at all facilities is increased up to 60 percent over current levels (5 percent at Fairchild and McChord), primary care recapture continues to increase but with diminishing marginal returns. The most significant contribution is from family practice, with little benefit from internal medicine beyond a 20 percent productivity increase. This is partly due to a shifting of primary care from internal medicine to family practice. This shift is driven by the fact that substitution has been occurring with some internal medicine specialists providing primary care. As productivity increases, primary care transitions from the internal medicine specialists back to a more clinically appropriate setting. This effect is seen in a number of instances in the provider productivity analysis. This is also consistent with the current plan to focus reengineering on family medicine in the region.



As primary care productivity is increased, recapture continues to increase, but with diminishing returns. Most significant contribution is from family medicine, with little benefit from internal medicine beyond 20%

FIGURE 2: THE IMPACT OF INCREASED CLINIC PRODUCTIVITY ON VISITS

Simulation-based analysis allowed for a more robust study of the impacts of an increase in primary care provider productivity in Region 11 than could be accomplished through more traditional analysis. This analysis allowed for the discovery and subsequent analysis of several second-order effects critical to the provider productivity analysis, through the simulation model's more realistic representation of episodes of care. First, opportunities for referring in-house specialty visits were identified and quantified by specialty for the region and each MTF. Second, experimenting with changes in capacity led to insight into the extent of substitution between primary care specialties (e.g., internal medicine picks up a bigger portion of primary care workload when the availability of appointments is low in family medicine). When the number of available appointments increases in family medicine, then the internists are free to see sicker patients or substitute for internal medicine sub-specialists (e.g., endocrinology, gastroenterology, infectious disease, etc.).

Medical Deployment Analysis

The impact of a major medical deployment is the subject of the third analysis question. TRICARE Northwest's mission is to create an environment in which it can, "in a fiscally responsible manner, collaborate to promote, protect, maintain and improve the health and wellness of those entrusted to our care while supporting our military commitments." Supporting military commitments entails the readiness to deploy medical assets on short-notice throughout the world. While this commitment is mission critical, it has impacts on the delivery of day-to-day healthcare services to the beneficiary population. Specific issues examined included the impact of the loss of provider and support staff, contributions of backfill assets to absorb the loss of productive capacity, and costs of the deployment.

The assumption was made, for the purposes of this study, that approximately one-fourth of the fleet hospital departed on short notice for a ninety-day deployment. The deployed component of the Fleet Hospital platform consisted of 242 personnel of a specified mix and quantity of providers, nurses, and support personnel. Under this scenario there was no full or partial presidential mobilization (call-up), therefore, Reserve backfill was on a voluntary basis. Manning assistance from other MTFs was not considered an option.

The analysis design for the medical deployment analysis consisted of conducting initial simulation runs with current provider capacity to establish a starting point or baseline for the analysis. From the baseline view, the loss of all direct care providers was assessed separate from the degradation impacts of support staff. Then support staff impacts were assessed with various runs of the model. Finally, a range of backfill options was explored to determine a range of possible impacts. Impact of support staff was assessed through four model runs, as summarized in the following:

- First, providers were deployed but the provider to staff ratio remained constant (no additional impact)
- In the following three model runs, providers deployed and staff reduction impacts degraded provider capacity by an additional 5, 10, and 20 percent

One model run (degrade provider capacity by an additional 10 percent) was selected for further study. Three backfill rates were run over the course of the deployment at the 16th, 31st and 45th day, respectively, to review varying levels of impact.

This simulation-based analysis projected that the cost increase for purchased care would be approximately $1.0 to $1.2 million as a result of a three-month deployment. The ability to reduce this requirement through backfill is highly sensitive to the timing and nature of the backfill employed. Under the most aggressive backfill assumptions studied in this analysis, as much as 50 percent of the total cost of purchased care can be saved. In this analysis, several backfill options were explored. The model is capable of providing regional planners literally hundreds of model projections by varying critical backfill options (who, when, where) and has the ability to arrive at, for a given deployment, the "best" backfill strategy (among realistic options) to minimize cost.

SIMULATION MODEL OF LONG-TERM DISEASE MANAGEMENT AT WILFORD HALL MEDICAL CENTER

During September 2001, the DoD contracted with VRI to explore the potential of simulation-based analysis for goal 2, as directed by the National Defense Authorization Act. The purpose of this study was to analyze the impact of adopting disease management practices on the future demand for the adult intensive care unit (ICU) at Wilford Hall Medical Center (WHMC) in San Antonio, Texas. An increased demand for trauma related care has put a strain on limited resources in the critical care arena. Simulation modeling allows testing of various scenarios that would allow for maximum benefit given the current resource constraints and help project ICU needs at Wilford Hall in anticipation of growth in trauma care during the next 15 years.

The Wilford Hall ICU serves patients from the WHMC beneficiary population and civilian emergency patients from the San Antonio area. The former patients enter the ICU through both the WHMC emergency room (ER) and through other routes such as surgery, non-ICU hospital beds, and clinics. The latter patients enter the ICU primarily via the ER, and are also served by two other major medical centers in San Antonio: Brooke Army Medical Center (BAMC) and University Hospital. The adult ICU itself is partitioned into medical ICU (MICU) beds, surgical ICU (SICU) beds, and coronary

ICU (CICU) beds, and also includes several "step-down" progressive care unit (PCU) beds, for a total of 30 ICU beds and 6 step-down beds. A separate pediatric ICU, which serves all patients less than 15 years of age, was not included in this study.

Characterizing ICU Utilization

To illustrate the potential impacts of long-term disease management on ICU usage at WHMC, a detailed understanding of ongoing and prior usage patterns was required. One purpose for developing this characterization of ICU use was to identify diseases that place a heavy demand on the ICU and that might be reduced by adopting disease management practices. Figures 3 and 4 list the most prevalent diagnoses of patients in the ICU from FY 96 through FY 01. Diseases on the lists for which disease management might be beneficial are highlighted. Primary diagnoses are shown in Figure 3 and secondary diagnoses are listed in Figure 4 (because MHS data sources list up to seven secondary diagnoses and the exhibit counts all secondary diagnoses associated with an admission, the patient and bed day counts on Figure 4 include multiple counts for some patients).

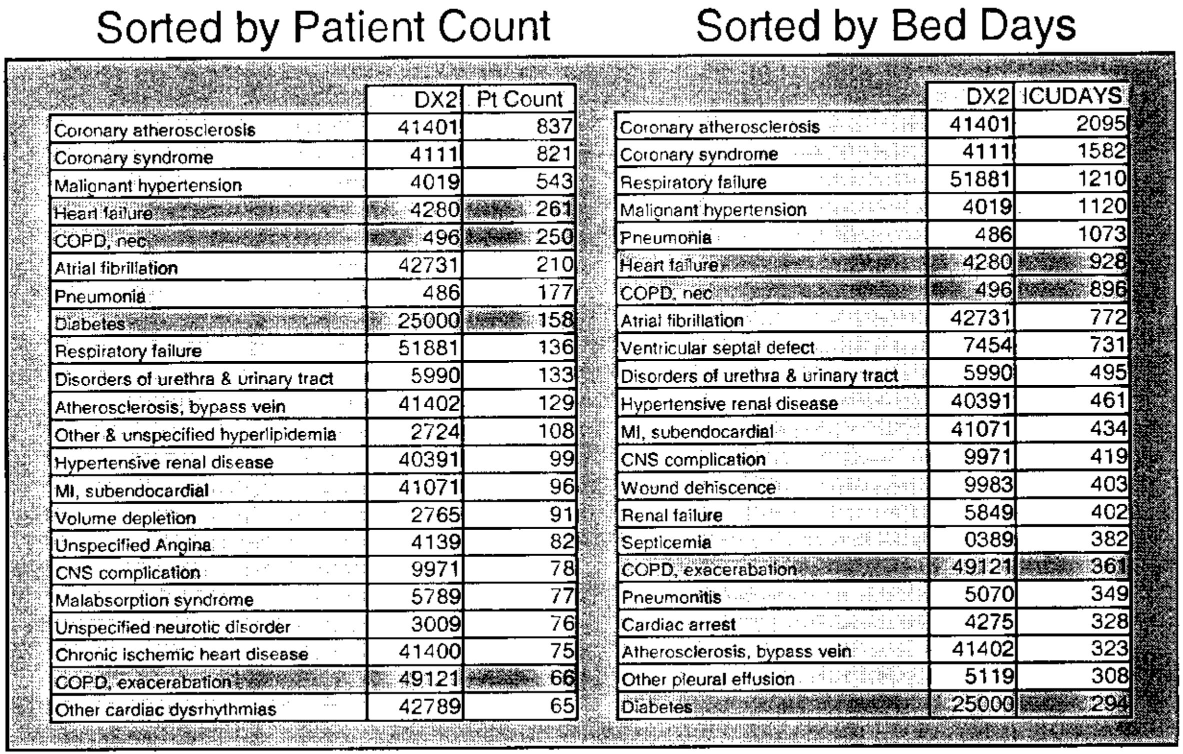
Sorted by Patient Count

	Dx	Pt Count	No. ICU Days
Coronary atherosclerosis	41401	1424	3160
Heart failure	4280	428	1409
GI Hemorrhage	5789	298	823
Pneumonia	486	272	1498
Carotid artery occulsion	43310	245	320
MI, subendocardial	41071	234	834
Chest pain	78650	213	250
Atrial fibrillation	42731	183	385
Chest pain, symptoms	78659	180	212
Coronary syndrome	4111	173	229
COPD Exacerbation	49121	158	664
MI, unspecified site	41091	149	441
Abdominal aneurysm	4414	124	721
MI, interior wall	41041	121	277
Atherolsclerosis, bypass vein	41402	114	277
Respiratory failure	51881	108	1024
COPD, nec	496	106	468
Morbid obesity	27801	106	392

Sorted by Bed Days

	Dx	Pt Count	No. ICU Days
Coronary atherosclerosis	41401	1424	3160
Pneumonia	486	272	1498
Heart failure	4280	428	1409
Respiratory failure	51881	108	1024
MI, subendocardial	41071	234	834
GI Hemorrhage	5789	298	823
Brain conditions, other	3488	4	734
Abdominal aneurysm	4414	124	721
COPD Exacerbation	49121	158	664
Pancreatitis	5770	44	622
COPD, nec	496	106	468
MI, unspecificed site	41091	149	441
Septicemia	0389	68	411
Aortic valve disorder	4241	73	400
Morbid obesity	27801	106	392
Atrial fibrillation	42731	183	385
Subarachnoid hemorrhage	430	49	360
Cerebral vascular disease	436	83	334
Intestional obstruction	5609	32	330
Carotid artery occulsion	43310	245	320
Renal Failure	5849	71	318
MI, unspecified site	41011	98	305

FIGURE 3: MOST PREVALENT PRIMARY DIAGNOSIS OF ADULT ICU PATIENTS



Sorted by Patient Count

	DX2	Pt Count
Coronary atherosclerosis	41401	837
Coronary syndrome	4111	821
Malignant hypertension	4019	543
Heart failure	4280	261
COPD, nec	496	250
Atrial fibrillation	42731	210
Pneumonia	486	177
Diabetes	25000	158
Respiratory failure	51881	136
Disorders of urethra & urinary tract	5990	133
Atherosclerosis, bypass vein	41402	129
Other & unspecified hyperlipidemia	2724	108
Hypertensive renal disease	40391	99
MI, subendocardial	41071	96
Volume depletion	2765	91
Unspecified Angina	4139	82
CNS complication	9971	78
Malabsorption syndrome	5789	77
Unspecified neurotic disorder	3009	76
Chronic ischemic heart disease	41400	75
COPD, exacerabation	49121	66
Other cardiac dysrhythmias	42789	65

Sorted by Bed Days

	DX2	ICUDAYS
Coronary atherosclerosis	41401	2095
Coronary syndrome	4111	1582
Respiratory failure	51881	1210
Malignant hypertension	4019	1120
Pneumonia	486	1073
Heart failure	4280	928
COPD, nec	496	896
Atrial fibrillation	42731	772
Ventricular septal defect	7454	731
Disorders of urethra & urinary tract	5990	495
Hypertensive renal disease	40391	461
MI, subendocardial	41071	434
CNS complication	9971	419
Wound dehiscence	9983	403
Renal failure	5849	402
Septicemia	0389	382
COPD, exacerabation	49121	361
Pneumonitis	5070	349
Cardiac arrest	4275	328
Atherosclerosis, bypass vein	41402	323
Other pleural effusion	5119	308
Diabetes	25000	294

FIGURE 4: MOST PREVALENT SECONDARY DIAGNOSIS OF ADULT ICU PATIENTS

Among primary diagnoses, heart failure and chronic obstructive pulmonary disease (COPD) are frequently appearing diseases for which disease management is viable. When secondary diagnoses are considered, diabetes can be added to the list. Diabetes is a frequent secondary diagnosis that causes — or at least aggravates — the primary condition that required the ICU admission. There appears to be a potential to reduce future ICU utilization with implementation of comprehensive disease management programs for these three diseases.

The COPD Model

The COPD model was designed to represent the WHMC COPD population over a 14-year time period from FY 2002 through FY 2015. The purpose for the model was to estimate the impact of two alternative clinical programs, traditional care and disease management, on the health status of the COPD population and on the medical resources consumed in the treatment of COPD. In the context of this study, the model output of primary interest was the demand by this population on the WHMC ICU. The assumptions and structure for the model were developed from a review of the relevant clinical literature and in close collaboration with WHMC clinicians.

Two model runs were used to estimate and compare the population profile and resource consumption over time under traditional care and disease management. When disease management replaces traditional care, there is a significant shift in the consumption of resources, as Figure 5 illustrates. Application of disease management to COPD patients at WHMC is projected to reduce the frequency of exacerbations by approximately 17 percent. The overall impact of disease management on the ICU is approximately a 9 percent reduction in the total demand for bed days.

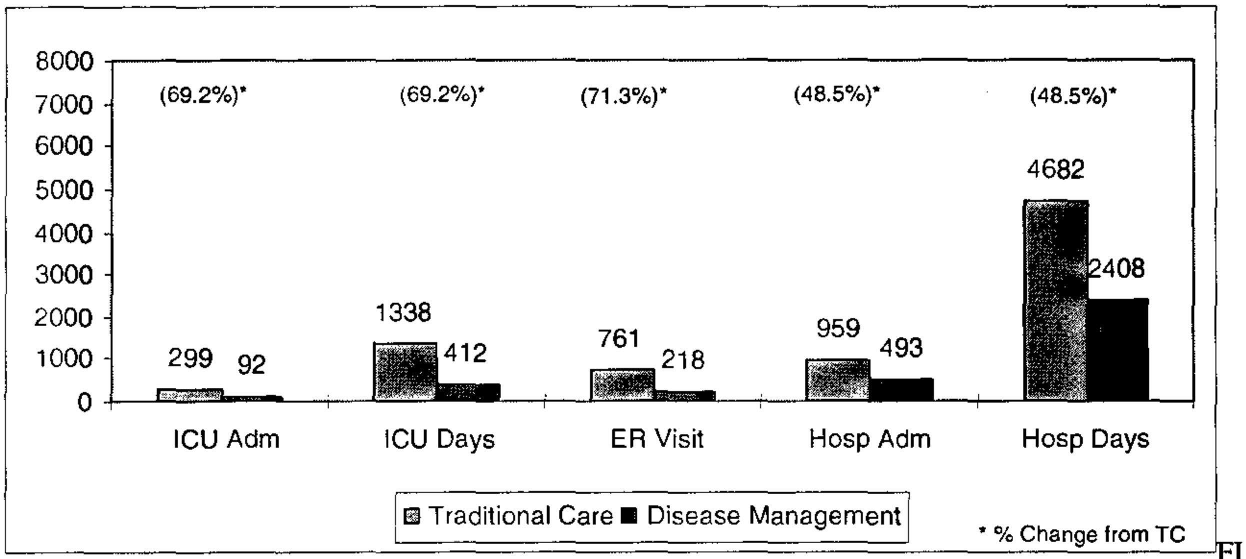


FIGURE 5: AVERAGE ANNUAL USE OF HOSPITAL RESOURCES BY COPD PATIENTS

The Heart Failure Model

The analysis of congestive heart failure is adopted from a model previously developed for a joint DoD–University of Texas Health Science Center clinical trial of heart failure disease management programs. WHMC and Brooke Army Medical Center (BAMC) patients made up one-third of the study patients; the remaining patients were Veterans Administration (VA), Medicare, and Medicaid patients. Disease management results in an increase in the number of patients occupying the less severe disease states and a decrease in the number occupying the most severe state. In addition, the overall size of the population increases under disease management. This is because disease management patients are more likely than traditional care patients to be in the less severe disease states. Mortality rates are lower in the less severe states than in the more severe states and are lower than the rates at which new heart failure patients immigrate into the population.

Projected utilization of hospital beds under the two programs is illustrated in Figure 6. There is an especially large reduction in ICU bed days consumed as a result of switching from traditional care to disease management. The reductions in demand for hospital resources occur even though disease management eventually serves a larger population than traditional care because of increased survival. As noted above, this is because much of the hospital utilization by heart failure patients occurs for patients in the more severe disease states, and there are fewer of these patients in the population under disease management, even though the total number of patients is larger.

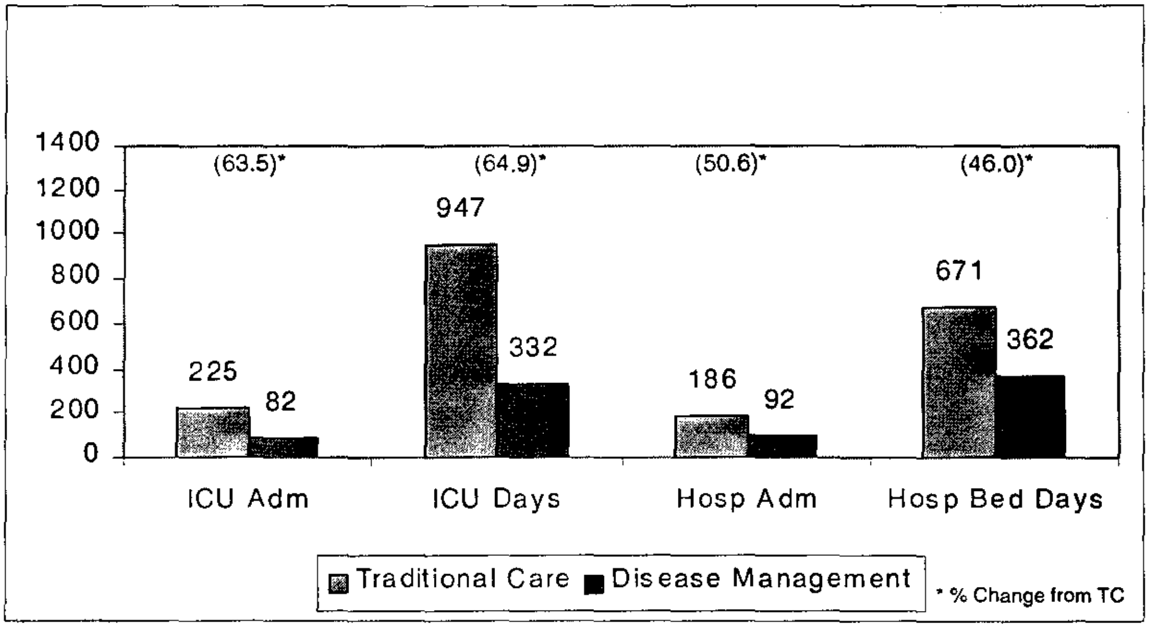


FIGURE 6: AVERAGE ANNUAL USE OF HOSPITAL BEDS BY HEART FAILURE PATIENTS

The Diabetes Model

The diabetes analysis employed a set of models previously developed to explore the application of diabetes disease management to the patient population served by WHMC and BAMC. These models include disease states that represent glucose control levels and progression of microvascular complications (retinopathy, nephropathy, and neuropathy). Glucose control complications account for most diabetes-related ICU admissions and bed days, and they generally occur with diabetes as a secondary diagnosis. That is, diabetes as a disease generates ICU use largely as a comorbid condition that aggravates or causes the primary condition, with cardiovascular disease the most prevalent primary condition. Glucose control affects the frequency and progress of the primary condition and is the principal goal of diabetes disease management.

After an initial transition period, disease management significantly increases the proportion of patients under tight glucose control. As a result, the prevalence of the most severe of the microvascular complications declines under disease management over time, diverging somewhat from the rate of serious complications under traditional care. Projected utilization of hospital beds under the two programs is illustrated in Figure 7. On a percentage basis, the reduction in both ICU utilization and use of other hospital beds is quite large, although the absolute magnitude of the ICU effect is relatively small compared with the savings in non-ICU bed days.

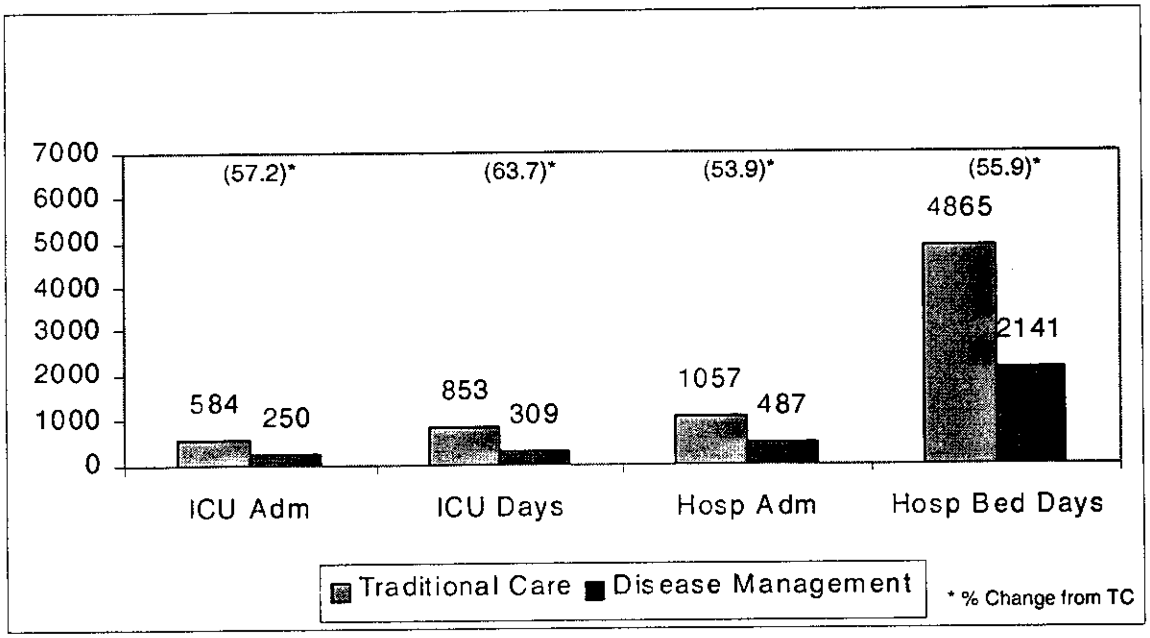


FIGURE 7: AVERAGE ANNUAL USE OF HOSPITAL BEDS BY DIABETES PATIENTS

WILFORD HALL MEDICAL CENTER INTENSIVE CARE UNIT REDESIGN

During September 2002 the DoD contracted with the Altarum Institute to conduct a follow on simulation study of the WHMC ICU. The purpose of the study effort was to support ICU redesign by investigating sizing and policy issues for the WHMC ICU involving:

- Changes in staffing levels (including changes associated with a medical deployment)
- Changes in bed availability
- Varying closure policies
- Varying internal transfer (or bed "partitioning") policies

The effects of various sizing and policy alternatives were measured in terms of the sufficiency of the patient condition case mix to satisfy Graduate Medical Education (GME) Program requirements, number of patients turned away and the amount of time the ICU was closed to new trauma patients. Although initial application of the model was to the WHMC ICU, the model is general enough to be adapted to analyses of ICUs in other hospitals within the Military Health System (MHS). The layout of the model is shown in Figure 8.

As noted earlier, the WHMC adult ICU consists of four separate units – a medical ICU (MICU) consisting of medical beds, a surgical ICU (SICU) consisting of surgical beds, a cardiac ICU (CICU) consisting of cardiac beds, and a progressive care unit (PCU), consisting of progressive (or "stepdown") beds. All but the cardiac beds occupy space on the second floor of the medical center – space that also houses a separate pediatric ICU (which was not analyzed in this study). The cardiac beds are located in a separate space on the third floor. The current bed configuration consists of 8 medical beds, 12 surgical beds, 10 cardiac beds, and 6 progressive beds.

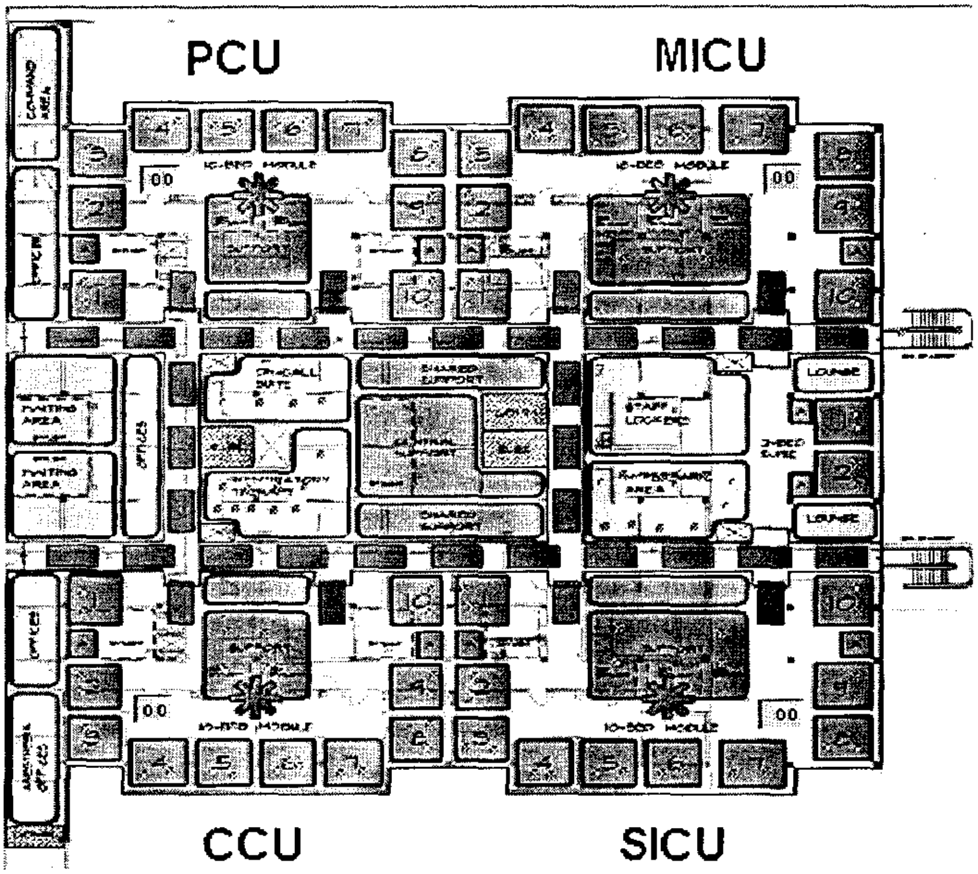


FIGURE 8: WHMC INTENSIVE CARE UNIT LAYOUT

Simulation Study Topics

Central to the redesign of the ICU was the issue of proper physical sizing, issues of ICU bed availability, the competing demands for ICU beds, and the impact of the constrained bed resource on other WHMC programs. The WHMC ICU is frequently closed to medical patients and less frequently to both medical and trauma patients based on the number of available ICU beds. The closures are a result of patient demand and nursing staff availability that directly affect the number of ICU beds that can be occupied. Military operational requirements, and resulting nursing staff deployments, result in reduced nursing staff for peacetime care, and can be expected to continue to affect ICU bed availability.

Two basic floor plans were proposed for redesign of the second floor ICU. A 34-bed option would allow for an eight-bed pediatric ICU and 26 additional beds to be allocated for use as adult medical, surgical, and progressive beds. A variant of the 34-bed option would involve relocating the pediatric ICU and dedicating all 34 beds to the three adult bed types.

A 42-bed option would allow for a ten-bed pediatric unit, leaving 32 beds to be allocated for adult use. This option would require significantly more extensive construction than the 34-bed option. For either redesign option, the cardiac beds would remain on the third floor, and would not be affected by the redesign. Phased development alternatives (such as near-term adoption of the 34-bed option and longer-term evolution to the 42-bed option as demand for the ICU increases) are possible. Funds were available for the 34-bed redesign. Additional funds would have been required to pursue the 42-bed design or relocation of the pediatric ICU. Each of these bed-option scenarios was used to investigate management issues in five general categories: size, closure policy, partitioning policy, exit or discharge blocking, and deployment impacts.

Optimal ICU Size

This analysis topic involved issues concerning redesign of the ICU, such as establishing the most effective size of the ICU (expressed as number of beds of each type that can be staffed) and identifying how this most effective size varies with time (and associated changes in the population served by the ICU). There were alternative configurations corresponding to the current ICU and three construction options for the second floor: the 34-bed option in which the pediatric ICU remains in the area, the 34-bed option but with the pediatric ICU moved to another location, and the 42-bed option. Within each construction option, several bed mixes were investigated. Each bed configuration is described using the notation M/S/C/P, where M represents the number of medical ICU beds, S represents the number of surgical ICU beds, C represents the number of cardiac ICU beds, and P represents the number of progressive care or stepdown beds. Figure 9 indicates the bed configurations investigated under this topic.

Construction Option	Current	34 Beds (with Peds)					34 Beds (w/o Peds)		42 Beds	
Bed Configuration	8/12/10/6	10/10/10/6	11/12/10/3	12/10/10/4	14/12/10/0	12/12/10/2	14/14/10/6	14/12/10/8	14/12/10/6	14/14/10/4
Total Facility ICU Beds	44	44	44	44	44	44	52	52	52	52
Second Floor										
Medical Beds	8	10	11	12	14	12	14	14	14	14
Surgical Beds	12	10	12	10	12	12	14	12	12	14
Progressive Beds	6	6	3	4	0	2	6	8	6	4
Pediatric Beds*	8	8	8	8	8	8	8**	8**	10	10
Total Beds	34	34	34	34	34	34	34	34	42	42
Third Floor										
Cardiac Beds	10	10	10	10	10	10	10	10	10	10
Total Adult ICU Beds	36	36	36	36	36	36	44	44	42	42

* Not simulated in this analysis

** Assumes pediatric beds are moved to another location

FIGURE 9: DEVELOPMENT OF ALTERNATIVE BED CONFIGURATIONS

Under conditions of current patient demand for ICU beds, bed configurations corresponding to the 34-bed construction option appear to provide a marginally acceptable performance of ICU. An example of the more effective of the bed configurations considered within this construction option is one that provides 11 medical beds, 12 surgical beds, 10 cardiology beds, and 3 progressive beds. This configuration was predicted to turn away approximately 9 percent of patients, with turned away patients reasonably well balanced in number across patient types. The case nearly complies with the Memorandum of Understanding (MOU) with the State of Texas requiring that the ICU be open to trauma patients 95 percent of the time. It essentially matches the base case with respect to the mix of patient conditions needed to support GME activities.

Given current demand at the time of the analysis, alternatives involving a larger adult ICU (either via adopting a 42-bed construction option or by relocating pediatric ICU patients away from the remodeled 34-bed unit) perform noticeably better than the basic 34-bed alternatives. Patients turned away were predicted to be reduced to less than half their levels under the 34-bed configurations, and all bed configurations examined are MOU compliant. However, these alternatives also achieved somewhat lower occupancy levels than with the 34-bed construction option, suggesting unused capacity.

As demand for the ICU increases over time, the 34-bed alternatives perform less well. Under patient demand levels projected for FY 2015, there is a near doubling in patients turned away, and none of the alternatives achieve the MOU threshold; (Most are open to trauma less than 90 percent of the time).

The larger ICU alternatives performed significantly better than the smaller alternatives given FY 2015 demand; (FY 2015 demand projections were developed during the disease management study described previously). Here, the typical bed configuration turns away less than 7 percent of patients, barely fails to comply with the MOU, and essentially matches the base case with respect to the mix of patient conditions needed for GME as seen in Figure 10.

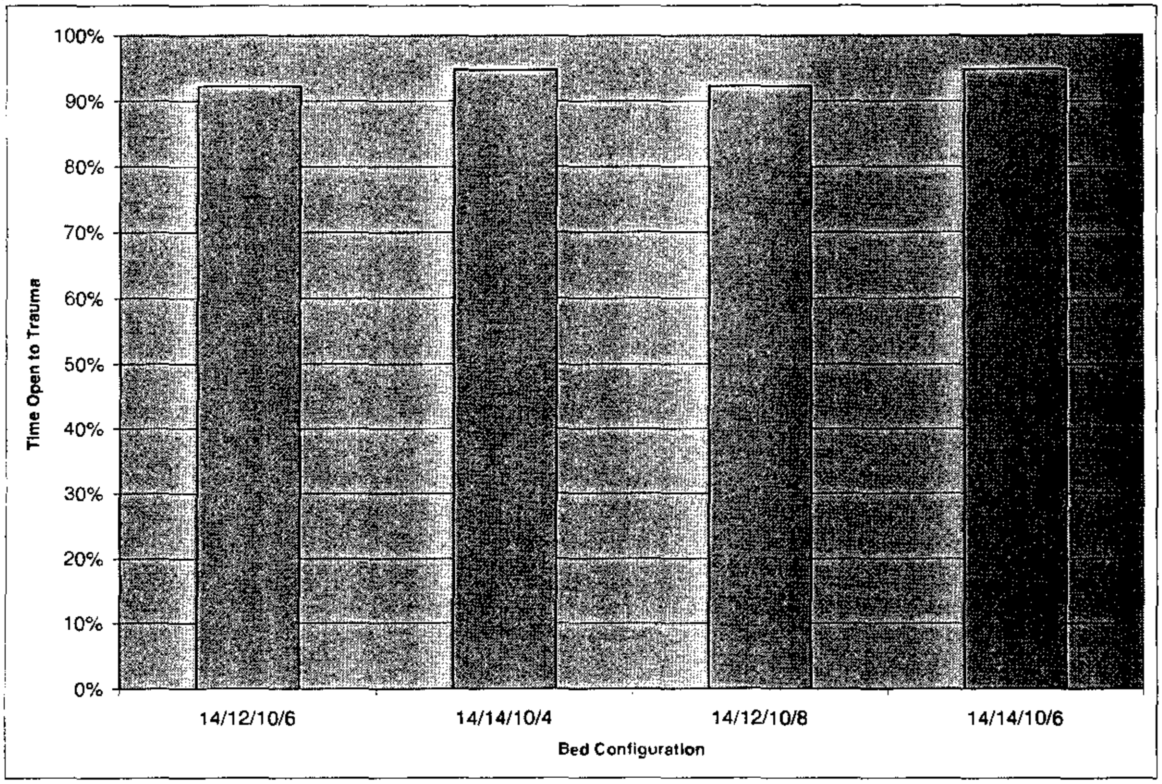


FIGURE 10: MOU COMPLIANCE – PERCENT OF TIME OPEN TO TRAUMA PATIENTS (FUTURE DEMAND, LARGER ALTERNATIVES)

These observations suggested to the leadership of the redesign effort that future ICU needs at WHMC might be met by selecting a 34-bed alternative in the near term and transitioning to a larger alternative at some time in the future. Given the projected rate at which demand will increase, no 34-bed alternative achieves the trauma patient MOU threshold after FY 2007. This can be viewed as a year by which ICU expansion becomes essential.

Under either near-term or long-term demand assumptions, the PCU appeared to be underutilized. For this reason, some bed configurations that trade off PCU beds for more ICU beds result in improved ICU performance. In fact, MOU compliance appears to require this type of trade off.

Many of the above results can be described in terms of the relationship between bed occupancy rate and ICU congestion (as characterized, for example, by number of patients turned away). Congestion increases with occupancy rate, and increases significantly with occupancy rates greater than 75 percent of capacity. This suggests than any new or reconfigured ICU that is designed to operate near capacity will have significant access problems.

Optimal Closure Policy

Closure policy refers to rules by which the ICU is closed to one or more types of patient when near capacity. Such a policy is designed to ensure that the ICU will remain open to other patient types. This topic involved identifying the impact of alternative closure policies on ICU operations. To explore this topic, two closure policies were investigated that have been employed in the past in the WHMC ICU. The first involves closing the ICU to medicine patients when only one ICU bed (of any of the three types – medical, surgical, or cardiac) remains unoccupied; the second involves closing the ICU to trauma patients when only one ICU bed remains unoccupied as shown in Figure 11.

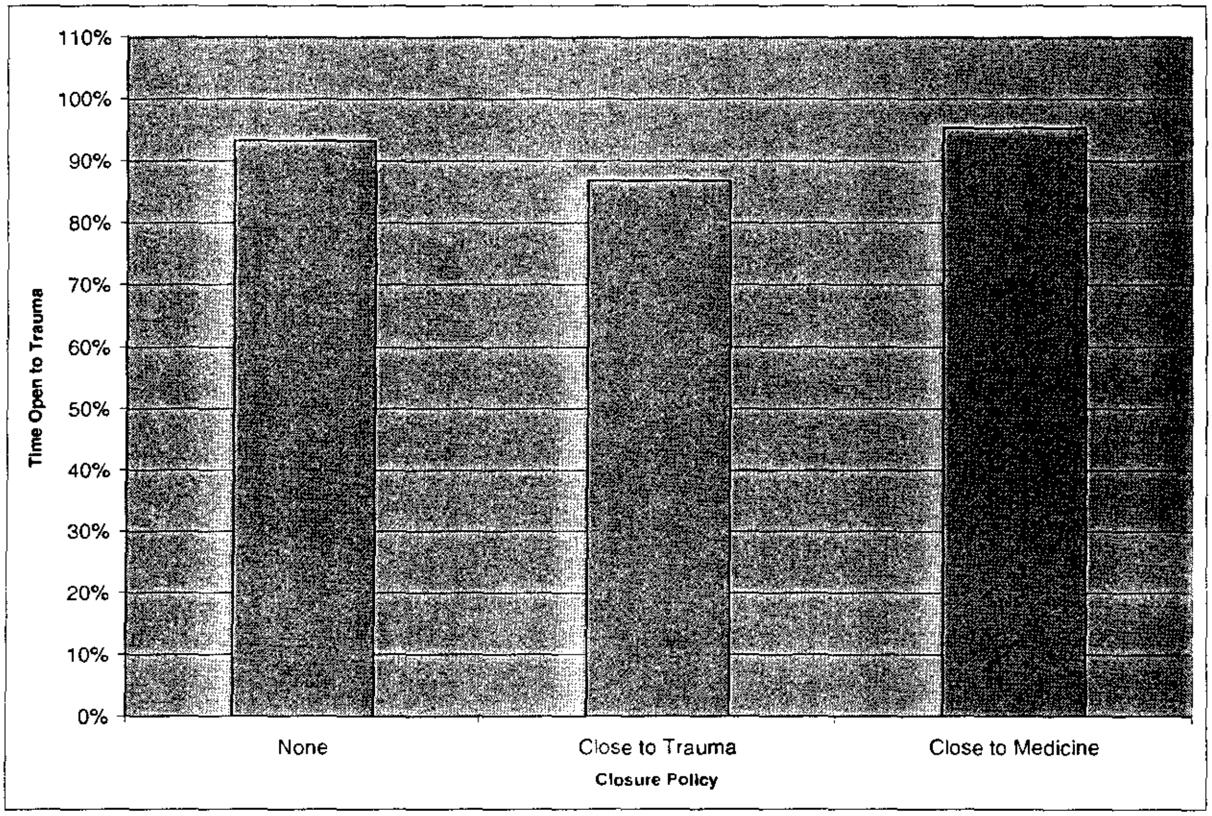


FIGURE 11: MOU COMPLIANCE AS FUNCTION OF CLOSURE POLICY (CURRENT DEMAND, 11/12/10/3 ALTERNATIVE)

An analysis of the sensitivity of ICU performance to bed closure policy indicated that closing the ICU to one patient type when a single bed remains unoccupied has little effect on the total number of patients turned away and on bed occupancy, although, it does cause a change in the mix of patients turned away from the ICU. A closure policy that closes to medicine patients when the ICU is nearly full will increase the percent of time that the unit is open to trauma patients, because it rejects arriving medicine patients in favor of trauma (and other) patients that have not yet arrived. This suggests that use of closure policy might be a viable strategy for ensuring compliance with the trauma MOU in situations that otherwise fall slightly short of the 95 percent threshold.

Optimal Partitioning Policy

Partitioning policies limit the types of patients that can be assigned to certain types of beds (for example, requiring that medical patients be assigned only to medical beds, surgical patients only to surgical beds, etc.) These policies help align patients with the type of care required but restrict admissions somewhat. This topic involves identifying the impact of alternative partitioning policies on ICU operations.

Two partitioning policies were investigated within this topic. An extreme partitioning level restricts admissions of medical patients to medical beds, surgical patients to surgical beds, and cardiac patients to cardiac beds. An intermediate partitioning level allows admission of each of these three patient types to either of two bed types. Both policies allow trauma patients to occupy any of the three full capability bed types (hereafter referred to as ICU beds).

Most of the model excursions conducted in this study assumed that each arriving patient of a given type had a first, second, and third choice for a bed type, but that any patient requiring an ICU bed would be admitted to the ICU if a bed of any type was available. With this lack of bed partitioning, the mix of full-capability beds by type in a bed alternative has no impact on overall occupancy rate, number and mix of patients turned away from ICU beds, and percent of time that the ICU is open to trauma patients. Model excursions that did impose bed partitioning confirmed that the overall impacts of doing so were an improved alignment of patients with their preferred bed types, but with a concomitant reduction in access to the ICU, measured by patients turned away as shown in Figure 12.

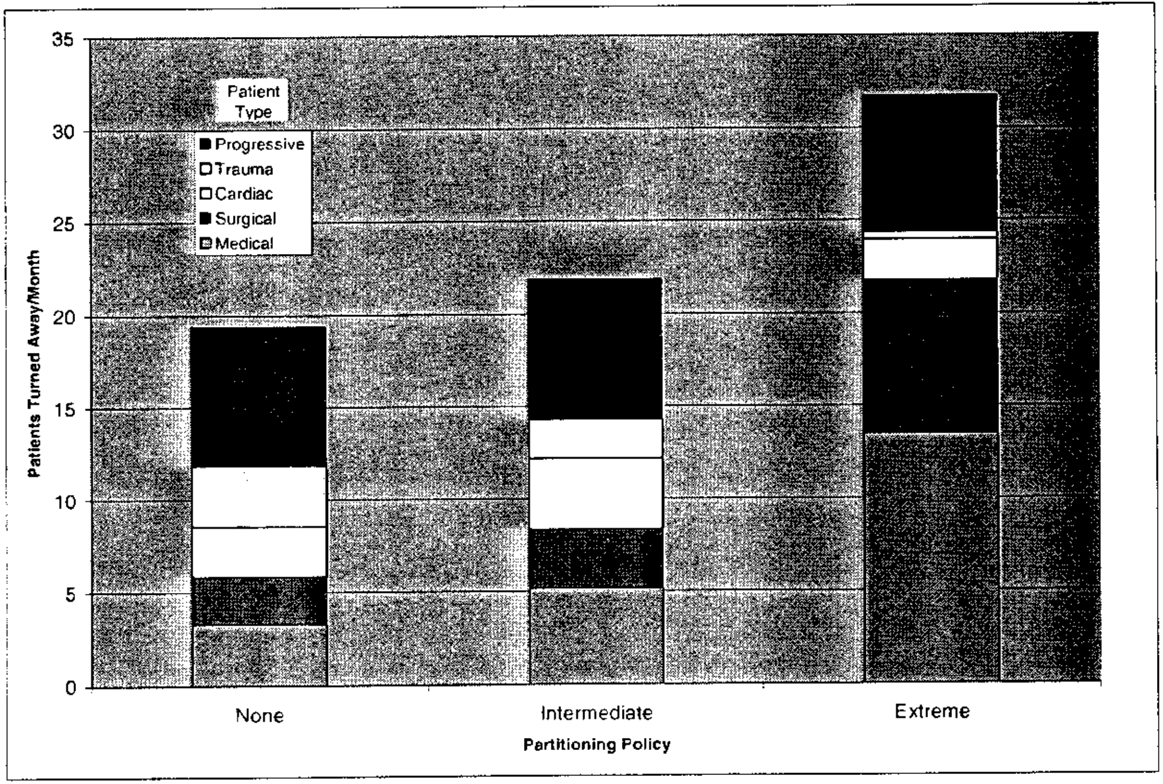


FIGURE 12: AVERAGE NUMBER OF PATIENTS TURNED AWAY AS FUNCTION OF PARTITIONING POLICY (CURRENT DEMAND, 11/12/10/3 ALTERNATIVE)

Exit Blocking

Exit blocking refers to the phenomenon in which a patient who is ready to leave the ICU must stay longer than required because of administrative delays or the unavailability of some resource (such as a bed elsewhere in the hospital) that is required in order for the patient to be moved. Exit blocking creates undesired congestion within the ICU. This topic involved investigating the impact of this congestion. This was done by estimating the fraction of patients who would be subject to exit blocking of a duration that was inferred from information in the WHMC ICU Log.

A sensitivity analysis (based on varying the proportion of exit blocking) on ICU performance indicated a moderate detrimental effect on number of patients turned away and a more modest negative effect on ability to comply with the trauma MOU. More significant degradation in performance could be expected if the average duration of blocking were greater than the 12 hours assumed in this analysis.

Deployment Impacts

A major medical deployment reduces the personnel available to staff the ICU, resulting in a requirement to close some beds. It simultaneously decreases the demand for use of the ICU because of reduced capacity in other areas of the hospital that feed the ICU and possibly a temporary reduction in the population served by the ICU. This topic involved investigating these effects and of policy changes that might help mitigate the effects. To investigate this topic, ICU bed availability levels and demand that corresponded to the recent deployment of medical personnel from WHMC to Afghanistan in late 2001 were identified. After simulating this situation, bed closure and policy alternatives that might mitigate the impacts of the deployment on ICU operations were explored.

A major medical deployment can have serious negative effects on the continued operation of the ICU in spite of the fact that demand declines somewhat during periods of deployment. These negative effects include large increases in the number of patients turned away, a significant degradation in the percent of time the unit remains open to trauma patients (see Figure 13 as an example), and large reductions in the patient condition mix required to support the training of residents. Closing the PCU under such circumstances (as in the third bar of Figure 13) alleviates all of these problems somewhat with respect to operation of the ICU beds (but requires that all patients who would otherwise be admitted directly to the PCU be treated in some other setting). Instituting a closure policy that closes the ICU to medicine patients when either one or two beds remain open (see the last two bars of Figure 13) provides some improvement in the time closed to trauma patients and improves the patient condition mix in all clinical areas except medicine without significantly increasing the rate at which patients are turned away from the ICU.

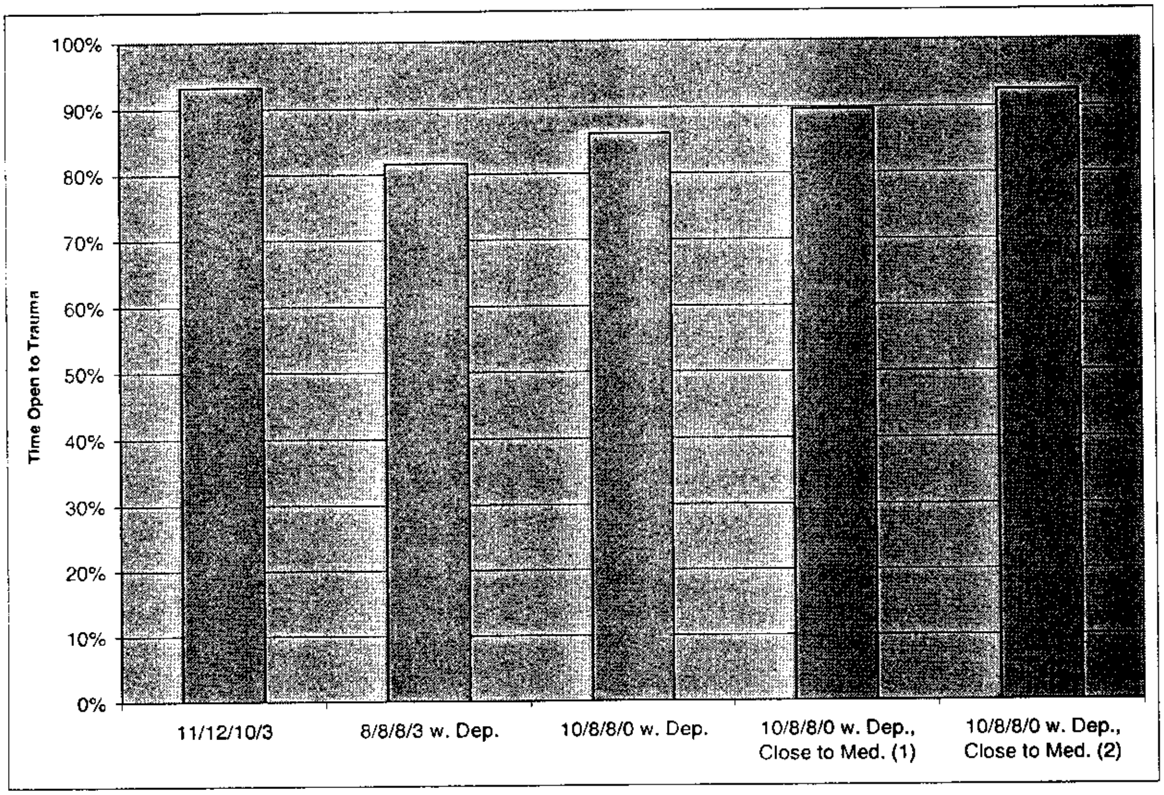


FIGURE 13: MOU COMPLIANCE DURING A DEPLOYMENT

SIMULATION MODELS OF CLINIC OPERATIONS

The Obstetrical Clinic Model (described previously in the section "The Use of Simulation Analysis Within the MHS") became the basis for work to develop a very generalized clinic model that has subsequently been used to represent OB clinics, primary care clinics, internal medicine clinics and pediatric clinics. The Department of Defense has contracted with Health Service Engineering, Inc. to extend this model to represent clinic processes at a number of locations including the Fairfax Primary Care Clinic of the Dewitt Army Hospital and three Camp Lejeune Outpatient Clinics. The purpose was to explore the effects of resource availability, patient volumes, and processing times on patient time spent in the system, and resultant patient satisfaction.

The basic clinic model is a discrete event simulation and is essentially the same model as the OB Clinic model with some minor changes. This model is highly significant because its use demonstrates the ease with which it can be projected into different clinical settings and it represents an evolutionary advance in its application. This project is unique in that numerous excursions were run and the output data were assembled in spreadsheet form so that clinic managers could select from a number of parameters and view modeled clinic performance. The model layout is displayed in Figure 14.

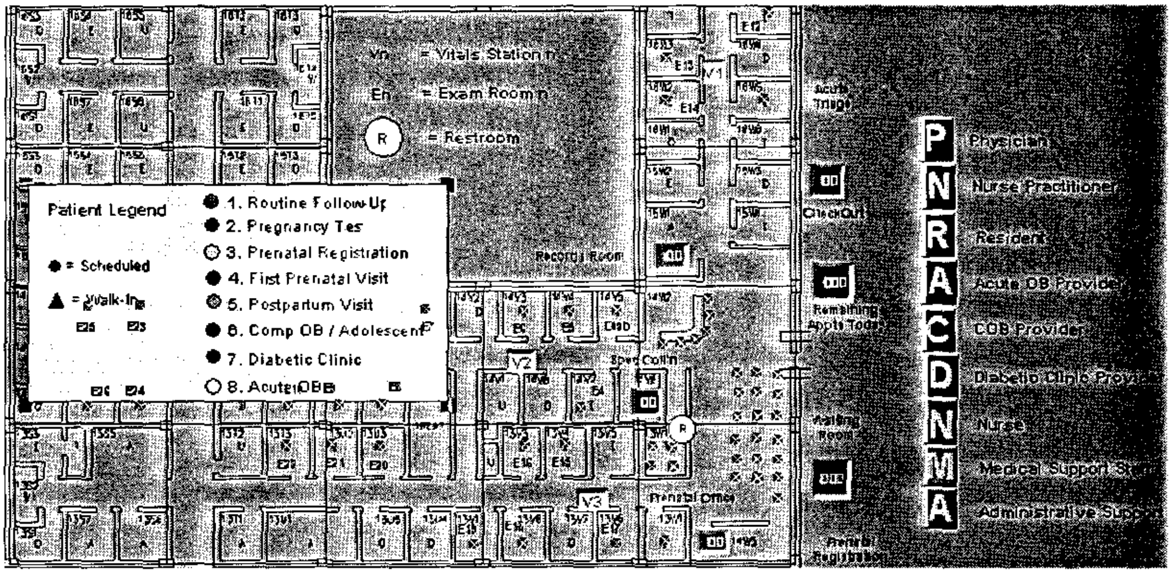


FIGURE 14: OB SIMULATION MODEL LAYOUT

The Spreadsheet Models

Output data from the basic clinic simulation model is exported into a spreadsheet tool for use by clinic managers to explore relationships among several selected variables. Full factorial experimental design on selected variables produced 2736 excursions for the Fairfax-based modeling effort. The model parameters that were varied are provider type (family practice, internal medicine, and pediatrician), whether vitals signs were taken inside or outside of the exam room, number of support staff for the two providers (2, 3, 4, and 5), number of exam rooms per provider (1, 2, and 3), patient volume and exam time.

The output data are organized into three separate spreadsheet versions based on the providers' clinical specialty (Family Practice, Internal Medicine, and Pediatrics). Figure 15 displays statistics associated with system performance in the Family Practice clinic.

System Performance Summary							
Number of Patient Visits	**Average Initial Wait**	**Average Wait for Provider**	**Average Time in Clinic**	**Average Session Overrun**	**Average % Provider Utilization**	**Average % S. Staff Utilization**	**Average % Exam Room Utilization**
20	0.0	0.7	19.9	0.3	54.1	30.8	31.2
22	0.0	1.1	20.4	3.7	58.7	34.0	33.9
24	0.0	1.7	20.9	5.5	63.5	37.7	36.6
26	0.0	2.6	21.8	8.1	68.0	41.9	39.2
28	0.1	3.2	22.4	10.7	72.4	45.7	41.7
30	0.1	4.5	23.8	14.0	77.1	51.2	44.2
32	0.5	6.4	26.1	18.6	80.8	57.6	46.4
34	1.1	8.1	28.4	26.5	83.7	62.8	47.9
36	2.2	9.8	31.2	31.4	87.3	69.1	49.8
38	4.4	11.5	35.2	42.8	88.4	74.1	50.7
All times are in minutes.							

FIGURE 15: EXAMPLE OF RESULTS in A FAIRFAX SPREADSHEET

A spreadsheet allows users to select values for four independent variables in the System Input Parameters box. Numeric values and graphs of these values are automatically updated to quickly show the user the effects of changing parameter values. A user can set the values of all variables except one to be the same across scenarios, then set alternative values for the variable not held constant to see the effects of that variable on system performance. In Figure 16, for example, the number of support staff differs in each scenario.

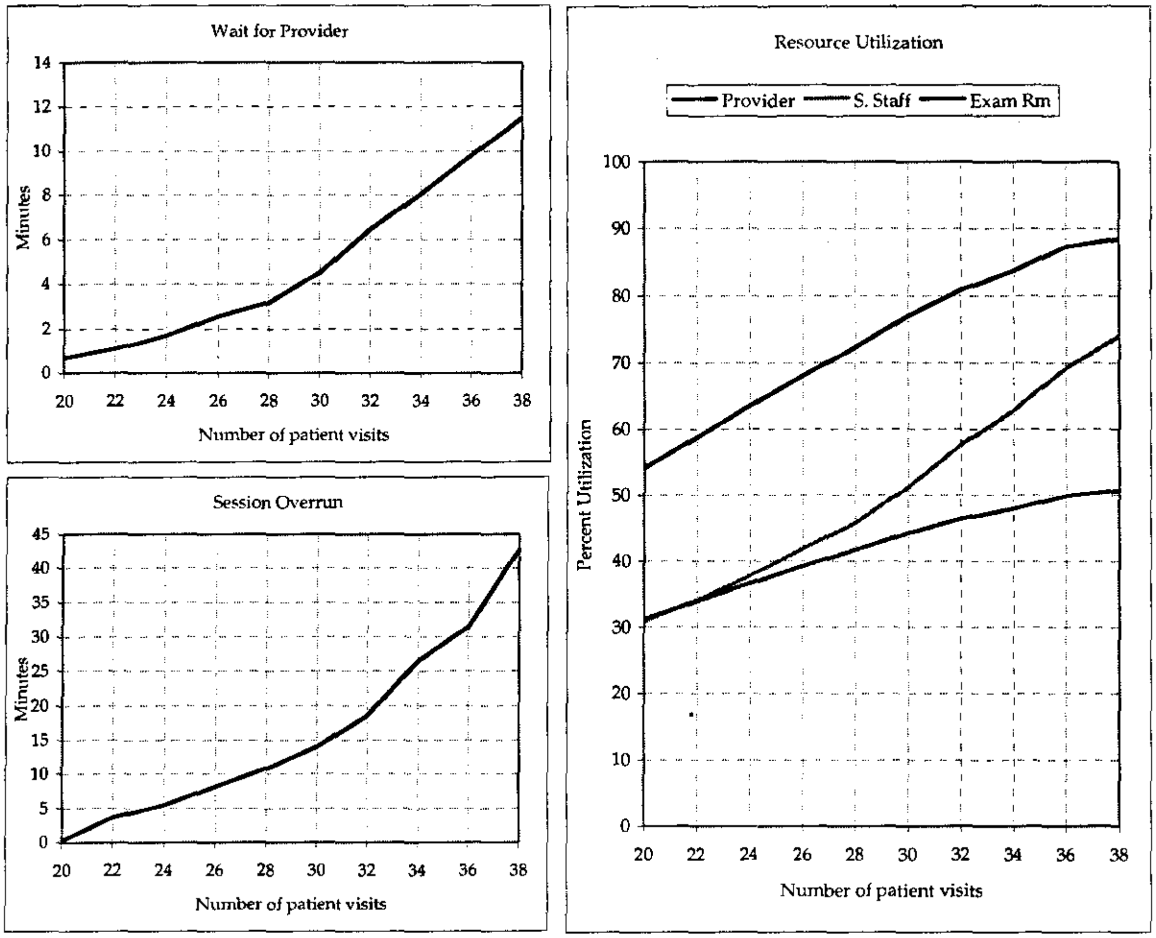


FIGURE 16: EXAMPLE OF VARYING SYSTEM INPUT PARAMETERS

The same basic simulation model was used to produce spreadsheets for the Anchor, Globe, and Pediatric Clinics at Naval Hospital Camp Lejeune (NC). These spreadsheets have a different format from the Fairfax spreadsheets and can report average clinic performance or performance given capacities that are sufficient 90% of the time. Scenarios can be described by various combinations of system input parameters.

CONCLUSIONS

In a number of earlier studies, the MHS demonstrated that well-designed models can suggest ways to improve performance at the ward or clinic level. Specific discrete-event models were designed to demonstrate the impact of changing clinical and administrative practices, resources, and facility design on the performance of the unit. The combination of the appropriate decision support tool with a management structure open to change resulted in improved performance. This utility has been confirmed more recently with development and use of a model of the WHMC ICU and a series of models of clinic operations.

Multi-facility simulation models, such as the model used in the Region 11 study, are designed to answer somewhat different questions. It is critical in times of constrained resources to understand the resource implications of policies at the MTF, catchment area, regional, and national levels. For example, an important question facing the MHS is how to best allocate limited resources across a region, Service, or across the entire MHS. High-level multi-facility simulation tools can be useful in predicting the outcomes of a given distribution.

Long-term disease management models, such as the model developed for the WHMC ICU, are designed to quantify the future demand for care and the impact that disease management may have on that demand and on patient outcomes. While one might have concluded that disease management is likely to reduce ICU demand without the use of a model, the quantitative analysis reviewed in this report has added useful detail to that observation. In particular, the analysis has helped to identify where to focus disease management efforts and has helped to quantify the magnitude of the benefit. Such quantification is particularly useful in the context of ongoing plans to restructure and resize the existing ICU. It seems clear that these resizing plans should be coordinated closely with plans to introduce disease management practices to ensure that the entire operation is reengineered to achieve maximum effectiveness. The demand-forecasting framework has potential utility for many future analyses. The representation of a variety of diseases in this type of model also provides an opportunity for another type of analysis with the model — prioritization of disease management efforts across conditions to focus on those conditions for which such efforts would be most cost effective.

Many of the applications reviewed here revealed counterintuitive (but correct) results and useful second-order effects that helped to enhance understanding of the systems under study. For example, the analysis of increased primary care provider productivity in Region 11 identified and helped quantify the impact of increased access to primary care with an increase in demand for subspecialty referrals. It also revealed several effects (such as scheduling inefficiencies) that would limit the ability to capitalize on improved provider productivity. Excursions with the WHMC ICU model identified the extent to which the ICU must be underutilized in order to ensure acceptable access to a bed in an emergency. When average bed occupancy rates are as low as 75 percent of capacity, the fraction of patients turned away tends to exceed the standards established for ICU operations. An analysis with the Fairfax simulation model exposed and explained several counterintuitive interactions between waiting times and the number of exam rooms available per provider. It is doubtful that such insights would have occurred without the use of dynamic models to support these analyses.

One reason most of these models are useful is that they were built with a specific analysis issue or other use in mind. This type of focused model development appears to be more effective than efforts to develop multi-purpose models with no specific planned application. This appears to be true even though the resultant model, if carefully designed, might have utility beyond the original application for which it was designed. As an example, early development work on the model subsequently used in the Region 11 study began in pursuit of a general-purpose model for representing the impact of telemedicine on healthcare delivery. It was only after the project became focused on a specific analysis topic – how to improve the utility of telemedicine in support of troops deployed to Bosnia – that a useful product was developed. This product has subsequently been useful for a number of non-telemedicine applications, including the Region 11 work.

With model development being a relatively costly endeavor, the ability to use a model for investigating new settings or analysis issues provides a way to leverage the development cost for other purposes. While development of models for a specific application tends to lead to models that are useful for the purpose developed, it can also lead to models that have limited utility for other analysis topics or settings. However, the models reviewed in this report, although originally developed for a specific use, were built with generic, data-driven structures allowing representation of new situations (including scalability to allow addressing larger or smaller operations than those for which they were originally developed) without changes to model logic. The model used in the Region 11 study (the Healthcare Complex Model), for example, was originally developed to address telemedicine issues, but subsequent enhancements and its general structure have made it applicable to a variety of healthcare process reengineering studies for deployed medical forces, counterterrorism activities, and peacetime care. These applications have simulated networks of facilities varying in scale from a single hospital to an entire TRICARE region. The model used in the disease management investigation (the Healthcare Management Model) was originally developed to analyze diabetes disease management, but its generic structure has allowed its easy adaptation to investigating several other diseases with populations of varying sizes. While the WHMC ICU model is specific to ICU operations and has not been applied in any settings other than WHMC, it has been designed to represent any ICU within the MHS via data modifications only.

Perhaps the best example of the generalizability of the models reviewed here was the ease with which the previously developed OB clinic model was modified slightly to produce the Fairfax simulation model, which in turn was modified slightly to become the Lejeune simulation model. Thus, with very minor code modifications (as well as appropriate data changes), one model structure served to represent the operations of OB, internal medicine, family practice, pediatric, and acute care clinics. This type of leveraging of the original modeling investment helps to ensure the cost-effectiveness of the modeling effort.

The MHS has a long history of developing automated clinical systems to support the patient-provider interaction and accounting tools to support the budget process. While these systems have important roles, they are limited in their ability to support the realization of cost-effectiveness goals and the management of constrained resources. The health care system is very gradually moving toward an "industrial" model where organizational structures and tools from other industries are being adopted. As that occurs, operations research tools such as simulation will become increasingly important. Simulation-based analyses offer the MHS the opportunity to address issues of supporting "best clinical" practice, determining the trade-offs inherent in managing constraints, and analyzing the complexities of disease product lines. These tools are vital to supporting DoD optimization efforts.

The Congressional funding enabled coordination of modeling and simulation at the level of the Secretary of Defense (OSD). This level of oversight encouraged regional-wide modeling that accommodated Army, Navy, and Air Force treatment facilities, along with contract support. Efforts to date in developing a common user database for modeling purposes indicate that additional coordination is needed to manage patient flow from the combatant theater to tertiary and rehabilitative care within the continental United States. The present work opened an additional set of tools for decision makers, but is in its infancy in the MHS.