USING SIMULATION TO IMPROVE THE OPERATIONAL EFFICIENCY OF A MULTI-DISCIPLINARY CLINIC

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Abstract

A recent trend in health care is to provide patients with the convenience of multi-disciplinary care during a single clinic visit. The University of Michigan Breast Care Center is a leading example of a multi-disciplinary clinic which has served the Midwest United States since 1985. A hallmark of this Clinic operation is a noon conference immediately following the morning diagnosis, where each case is discussed by a group of experts for immediate remedial action. The Clinic has seen significant increases in patient load over the years since its inception. The patient mix, initially all new patients, has matured, and returning patients are now a significant portion of the Clinic load.

Unfortunately, the huge success of the Clinic started to strain its smooth operation. Physicians were arriving late to the noon conference, which undermined the quality of care. Patients were complaining about long waits in the Clinic and delays in getting their next appointment. To examine these operational problems and to suggest remedial actions, a simulation study was conducted. This paper reports the results of this study. Our findings provide interesting insights into the operation and management of multi-disciplinary clinics.

1 Introduction

The number of clinics providing multi-disciplinary health care has increased substantially in the past decade. These clinics provide "one-stop" care which is convenient for patients and eliminates the long delays encountered in a series of physician referrals. Multi-disciplinary clinics have also increased the quality of care by facilitating direct contact and discussion of patient cases among physicians of different specialties. The recent emphasis on managed care has prompted insurers, hospitals, doctors and medical suppliers to regroup into health-care networks offering one-stop shopping for patients [2]. Efficient operation of multi-disciplinary clinic is essentials for cost-effectiveness and quality of the care.

The University of Michigan Breast Care Center (BCC) was established in 1985 to provide comprehensive, multi-disciplinary diagnosis and treatment of both benign and malignant breast disease. Meeting patient needs for efficient, rapid, and convenient evaluation is a priority. Emphasis is placed on providing an array of multimodality services in one location during a single visit. In the years since its inception, the clinic has attracted patients from all over the Midwestern United States. The reputation of the BCC itself has grown along with its practice. In 1992, it received a commendation for the best clinic at the University of Michigan Hospital. Mostly from the success of the BCC, the University Hospital itself has become well known as a leading provider of multi-disciplinary care.

The BCC operates for four hours from 8 a.m. to noon each Monday morning. This time was selected primarily to accommodate the intense workload of the participating physicians: surgical oncologists, radiation oncologists, and internal medicine oncologists. Patients come to the BCC by either physician or self-referral. Due to the serious nature of their condition, all new patients (NPs) are scheduled into the next BCC session. At the time initial visits are scheduled, a specially trained clerk instructs patients to bring to the evaluation mammograms, pathology slides, and other appropriate information. In addition to the NPs, the clinic also accommodates return visit patients (RVs) who require either continuing care from the surgical oncologists or interdisciplinary care. These RVs are scheduled because of complications, onsets of new cancer, or routine checkups. Radiation oncologists also see RV patients from other clinics with which they are involved. These RVs are primarily scheduled to maintain a high level of utilization for the radiation oncologists.

The BCC is under the guidance of a part-time physician director and a full-time clinical nurse specialist. In cooperation with an advisory executive committee comprised of BCC participants and a hospital representative, they are responsible for administration of the unit, generation of new initiatives, and facilitation of breast-related research endeavors.

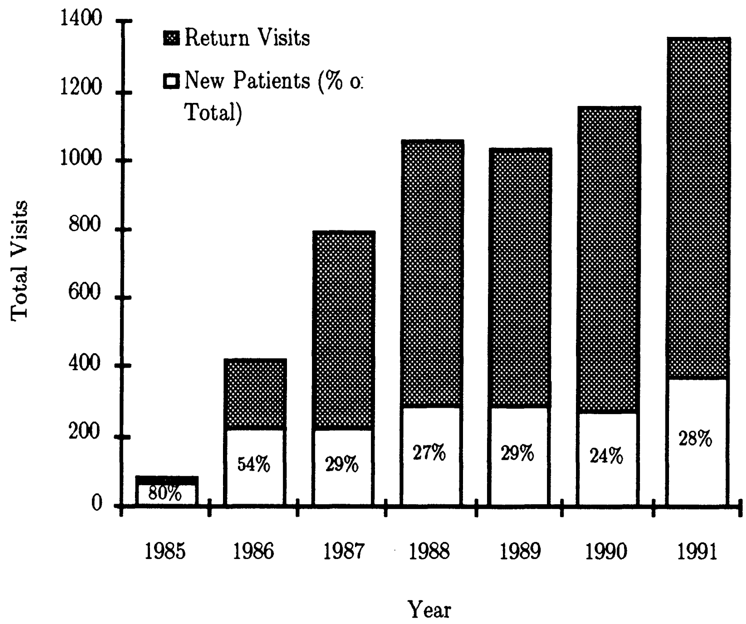

Figure 1: BCC Patient Visits 1985-1991

Since 1985, patient activity in the BCC has increased sixfold. The patient load of the Clinic (initially all new patients) has matured, and return visits are now a significant portion of the current case load (See Figure 1). The current scheduling system evolved from the scheduling template for individual providers, and does not reflect any anticipation of changes in patient mix or load. The current scheduling template has an insufficient number of appointment slots, which are scattered through the first two hours of the clinic. With the increased load, many patients are scheduled simultaneously and must endure significant waits prior to service. The change in patient mix has also affected clinic operations. The current scheduling system was designed to accommodate only a small percentage of RVs. The RVs usually have only one encounter with a physician. The physician that they see, however, is rendered temporarily unavailable for multi-disciplinary patient consultation, which has a cascading effect of delaying encounters with other physicians. This breakdown in coordination increases patient residence times and delays the end of the clinic. A significant advantage of the BCC is a noon-hour conference where physicians and other specialists meet and discuss each patient. Unfortunately, the delays in physician arrival reduced the conference effectiveness.

To address the late arrival to the noon conference and long patient residence times, the hospital administration requested an analysis of the Clinic operating procedures. An initial survey of Clinic participants underscored the severity of the problems related with clinic operation. New patients saw the appointment system as flawed, since due to overbooking, they were seldom admitted at their appointment time. In addition, patients were often admitted based on their arrival time, rather than appointment time. Return visits complained that they spent too much time waiting for a relatively brief encounter with a physician. Physicians were concerned about effective use of their time, and delayed arrival to the noon conference. Because patients were seldom ready at the beginning of the Clinic, physicians were inclined to arrive late. Physicians were also troubled by the fact that many patients became available for encounters only towards the end of the Clinic, delaying physician arrival to the noon conference. The nursing staff coordinating the clinic felt that the scheduling system was hampering clinic efficiency. They drew attention to a parallel Monday morning clinic, the General Surgery Clinic (GSC). This clinic directly competed with the BCC by scheduling patients to be seen by the same physicians.

The complexity of the clinic operation makes it an ideal subject for a simulation study. The problem is made more difficult because of resource contention, and the need for coordination among various provider services. The uncertainty of the load profile further complicates the investigation of future clinic operation. The load for the Clinic is based on both the level of new patients and the propensity of individual physicians to recommend return visits. Simulation enables the modeling of both these factors. Finally, the choice of simulation as an analysis tool was dictated by the need to evaluate alternative methods of clinic operation without interfering with the current clinic operation.

Due to the novelty and complex nature of the multi-disciplinary care, little attention has been paid to this type of clinic. However, the body of literature describing simulation applications to health care and patient scheduling is quite substantial. Although a relatively new pursuit, the use simulation as a technique for evaluating the performance of hospital systems is gaining momentum.

Pallin and Kittell [7] describe an application of simulation techniques that helps evaluate the quality of care provided under different alternatives designed to streamline operations in an emergency room. Worthington [9] uses a spreadsheet simulation to explore the effects of capacity changes on wait lists for a series of related in-patient and out-patient care centers. Bodtker, Wilson and Godolphin [1] describe a simulation model of a hospital clinical laboratory. They were able to explore the effects of reallocating tasks among staff and potential amalgamation with another facility.

Methods of patient scheduling have also been a concern of Clinic management for many years. O'Keefe [6] addresses the wait time of patients at an outpatient department. He qualitatively discusses policies that ensure that physicians are kept busy while patients encounter only reasonable delays. More quantitative approaches to scheduling are presented by Soriano [8], Fries and Marathe [3], and Ho and Lau [5]. Soriano contrasts wait time distribution for patients scheduled under a individual appointment system and a two-at-a-time (block) system. He hypothesizes that the two-at-a-time system will increase physician utilization while providing a method for punishing tardy patients without subjecting all patients to excessive delays. Fries and Marathe extend this analysis by introducing a more general variably sized block scheduling plan. They present a dynamic program to optimally assign appointment times. Ho and Lau present a simulation model for comparing scheduling rules where explicit costs are defined for each unit of patient wait time and provider idle time. Unfortunately, these models are applicable only to clinics offering a single service to each patient. In contrast, this paper analyzes a clinic with the potential of providing a multitude of different interrelated services to each patient. Fortunately, the capability of simulation tools facilitates the modeling complexity necessary to evaluate the operating procedures of a clinic offering this type of service.

The primary goals of this simulation research project were:

1. To evaluate the scheduling process and patient mix control.

2. To reduce patient residence times.

3. To maintain a high level of physician utilization.

4. To aid in understanding the tradeoff between physician utilization and patient residence time for various patient load and mix.

5. To propose alternative scheduling templates and evaluate its impact on clinic operations.

6. To ensure completion of clinic operation by noon through changes in clinic scheduling and operation.

The purpose of this paper is to describe how the clinic operations were improved using simulation. The paper will explain and report data collection, model construction and scenario testing. It will focus on the following areas:

1. Determination and collection of the necessary data.

2. Construction and validation of a simulation module to model day-to-day clinic operation.

3. Guidelines to manage patient mix and load.

4. Design and evaluation of an improved scheduling system.

The rest of this paper is organized as follows. Section 2 describes the operation of the Clinic. Section 3 outlines how the data were collected. It also presents an analysis of the data which lays the groundwork for the development of the simulation model and a new scheduling system. Section 4 describes the philosophy and organization of the simulation model. It also discusses how this was validated. Section 5 discusses the development of a new scheduling rule. It also compares the performance of the new rule with the system-in-use at the time of simulation. Section 6 presents our approach to patient load smoothing and its impact on the system. Sections 5 and 6 together present key findings of this paper. Section 7 concludes the paper with a discussion of implementation difficulties, future uses of the simulation model, and implications for multi-disciplinary clinics.

2 Overview of the Current Clinic Operations

Each patient entering the BCC is assigned a specific provider. New patients (NPs) are assigned to a specific surgical oncologists when their appointment is scheduled. Return visit patients (RVs) are scheduled to be seen by a specific surgical or radiation oncologist. When admitted into the clinic, all patients are initially assessed by a BCC nurse. Surgical oncologists then perform the first physical evaluation for NPs. They triage the NPs to see radiologists, radiation and internal medicine oncologists, plastic surgeons, psychiatrists, nurse specialists, and social workers as appropriate. RVs scheduled for the surgical oncologist (Surgical RVs) are treated in a similar fashion. RVs scheduled to see a radiation oncologist (Radiation RVs) receive their first and only evaluation from that physician.

In some cases, additional information is required for discussion at the noon conference. For example, outside breast imaging studies are reviewed before noon by a radiologist and outside pathology material by a pathologist. Simple procedures such as fine-needle aspiration biopsies may also be performed; these readings are also available before noon.

The patient cases seen during the morning are presented and discussed at the noon conference. The conference is attended by members of the specialties noted above and their technical support staff, gynecologists, representatives of the Tumor Registry, the Hospital Quality Assurance Committee, the Cancer Center Clinical Research Office, and basic and clinical researchers involved in BCC protocols. Evaluation and treatment recommendations are formulated, eligibility for clinical trials assessed, tissue procurement for studies planned, and follow-up problems and data are discussed.

3 Data Collection and Explication

Because development of the simulation involved both modeling clinic operations as well as describing patient loads, two approaches were used to gather the requisite data to formulate and calibrate the model. A patient flow survey was used to gather the information on clinic operations. Historical information from patient records was used to characterize patient volume and service requirements.

The patient flow survey was developed to gather data without interfering with patient encounters. To accomplish this, a survey form (see Appendix A) was created. This form tracked the timing, sequence, and location of services provided to each patient as well as the identity of the provider.

Providers helped complete the survey forms by documenting the start and end times of their encounter with patients. This survey facilitated the development of service time distributions and defined patient routing through the clinic. In addition, it provided wait-time information that was used to assist in validating the simulation model. Supplementary information, such as physician dictation times, discussions between residents and physicians, and encounters with patients at the General Surgery Clinic (GSC), was collected by actual observation.

Comparison of the patient flow forms lead to the realization that different NPs may require significantly different care. Close examination of NP routings yielded two distinct flow patterns which could be distinguished based on whether a patient needed interdisciplinary care or not. The same was true for Surgical RVs. This lead to a logical reclassification of the three patient types (NP, Radiation RV, Surgical RV) into five distinct care-oriented classes (see Figure 2). This new

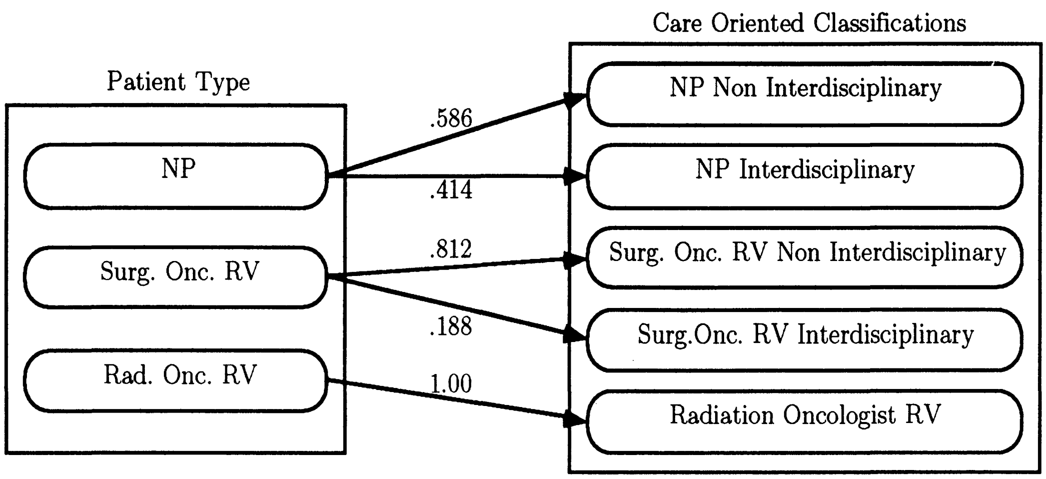

Figure 2: Care Oriented Patient Classification

classification provided a distinct routing for each care-oriented class (Appendices B-F) instead of a seemingly random routing for each patient. It also paved the way for the development of a new scheduling system discussed in Section 5. Another advantage of describing patients by the care oriented classification was the ease of translating the patient flow diagrams directly into simulation code segments.

The patient flow survey brought to our attention many important interactions between provider services. For example, an unusually long encounter between a patient and a provider often lead to a domino effect, delaying all subsequent providers scheduled to see that patient. This was a prime cause for the late arrival of physician to the noon conference. Another disruptive factor was the variability in service-time for similar encounters. A prime source of this variability was traced to the teaching responsibilities of the physicians. Residents were often instructed to see patients and then brief the physicians. This increased the patient wait-time and service-times substantially. In their desire to bring interesting cases to the attention of the residents, physicians often forgot that they might be delaying other physicians. The teaching mission of the physician could easily be fulfilled by scheduling residents when the case load was light. For some patients, an encounter with providers such as medical students and social workers could occur at any point during their visit. Since the possibility of cascading delays was not recognized, no attempt could be made to use this extra flexibility to assist in smoothing operations.

BCC records were used to gather historical arrival and service information. This information provided weekly counts for Surgical RVs, Radiation RVs and NPs. It also provided information on inter-appointment times and the total number of visits of a patient to the Clinic. NP load varied significantly from week to week, as shown in Figure 3. This underscored the need for careful

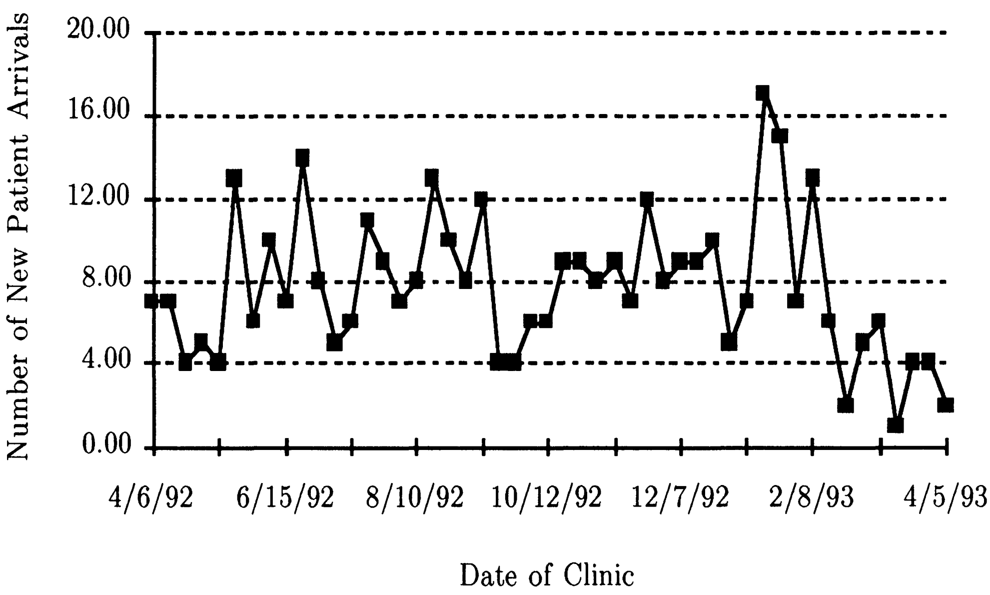

Figure 3: Sample year NP arrival pattern

scheduling of RVs, because the clinic followed a policy which always admitted NPs without delay. Since RVs provided scheduling flexibility, the total load could be made smoother, by adjusting RVs appointments. This was particularly important since the fluctuation in clinic load was a prime factor for creating delays in arrival of physicians to the noon conference.

There were also consistent periods of low and high loads. This prior information could be utilized for load levelling. Holiday seasons, for example, witnessed an extremely low load, followed by a surge during the following weeks. A possible explanation for this pattern is that people avoid going for breast examinations during the holiday season. Holiday get-togethers, on the other hand, raise awareness of the need for examinations which leads to a high level of incoming referrals in the months of January and February.

The percentage of patients that fell into each care-oriented class (see Figure 2) was determined from financial billing information, which contained descriptions of services. These percentages were used to calculate the expected clinic load for each physician type. A model is under development which uses factors such as demographic information, age, referral source, prior biopsy results, mammograms, comments from prior physicians, etc., to assign the likelihood of a new patient falling into a care-oriented class.

4 Description of the Simulation Model

This section describes the development and verification of the simulation model, including descriptions of the hardware and software used.

4.1 Equipment and Software

The simulation model was developed using General Purpose System Simulation (GPSS/H) [4] on a workstation. This software was selected because of its speed, flexibility, and sophisticated test mode which allows interactive debugging and easy validation of complicated model logic.

4.2 Model Organization

The model is comprised of three distinct modules shown in Figure 4. Described below is the input, output, and model logic for each module.

1. Patient Load Generator (PLG)

The PLG synthesizes historical data to provide a sequence of arrivals for the different patient types. Historical information on new patients arrival (similar to one shown in Figure 3) was used to extract the average number of weekly arrivals, the spread around the mean, the growth trend in new patient arrival, and the seasonality index. This information is used to generate future NP arrivals. Return visits are generated in two fundamentally different ways. The radiation RVs are generated using historical information in a similar manner to the NPs. In contrast, the surgical RVs are generated by scheduling a fraction of NPs and surgical RVs for another visit. The proportion of patients who are scheduled for such return visits varied greatly by the specific provider. This proportion, known as *RV retention*, plays a central role in determining the rate of growth for surgical RVs and in defining the patient mix. NPs were far more likely to be scheduled for a return visit than surgical RVs.

2. The Scheduling Module (SCM)

The SCM assigned an appointment time to each patient generated by the PLG using a *scheduling rule*. This time was selected from a scheduling template, sort of an appointment book with fifteen minute slots for each provider. The choice of scheduling rule was central in determining how templates for future weeks are filled, or when a return visit patient receives her next appointment. Since the clinic provides an immediate appointment for all NPs, there was no flexibility in scheduling them. A typical scheduling rule may set an upper limit on the number of RVs scheduled for a given Monday to regulate the total load on the Clinic. It may also aid in sequencing different types of patients to facilitate a smoother flow of patients through the clinic. "What if" analyses could be performed by trying alternative scheduling rules. The SCM provided statistical output on delays until next appointment, weekly load variation and variation in patient load mix.

3. Clinic Operations Simulation Module (COSM)

The COSM was the central module in this study which mimics the operation of the Clinic. It utilized

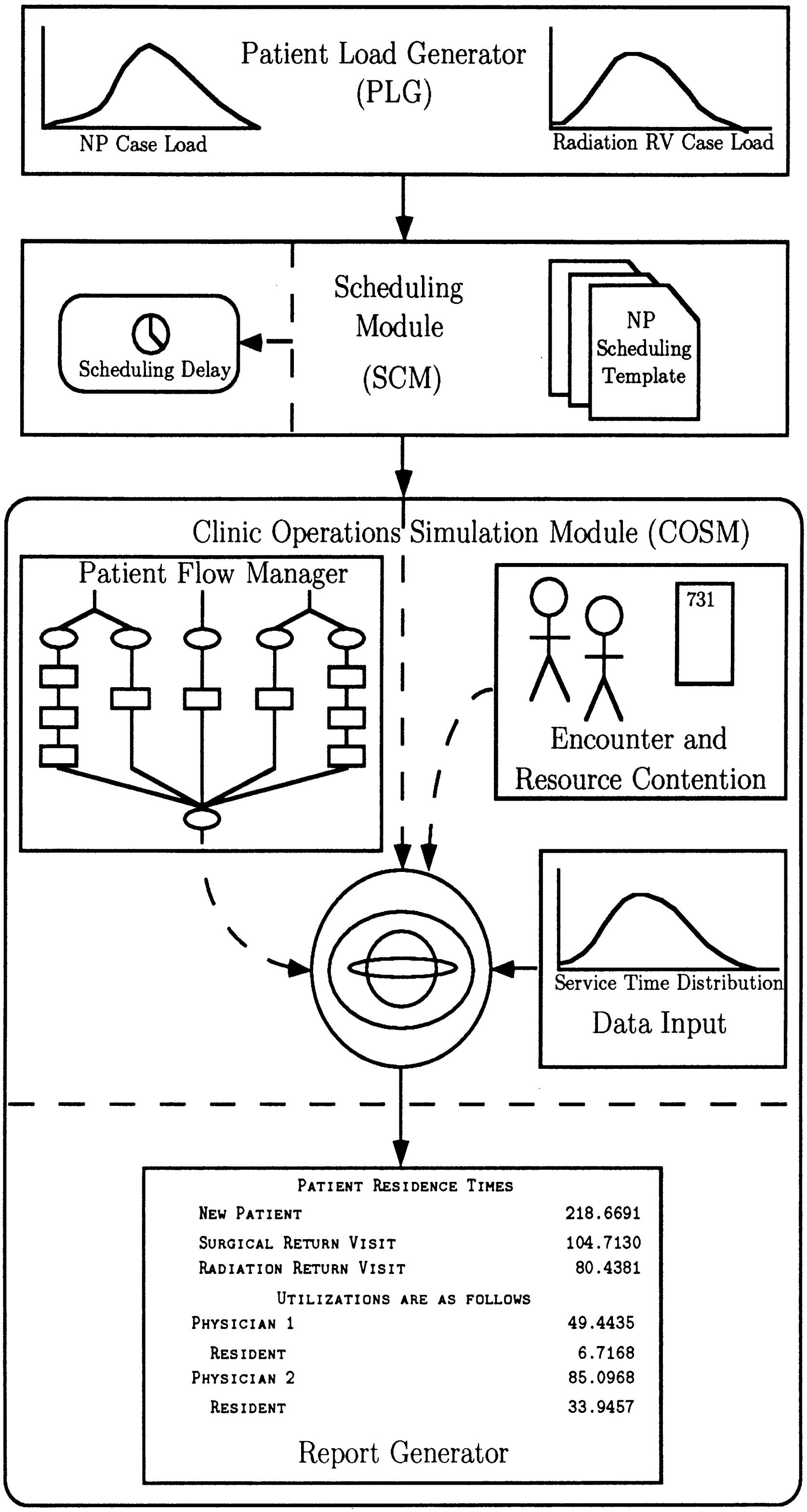

Figure 4: Organization of the Simulation Model

the detailed patient appointments generated by the SCM, information about various resources, and patient flow patterns to construct sample paths of clinic events. It collected performance measures such as resource utilizations, patient residence times, and delays in physician arrival to the noon conference. COSM was an integration of the following four segments, each designed to accomplish a specific task efficiently.

Patient Flow Manager. This was the largest program segment within COSM. It encoded the patient flow chart for each of the five care-oriented classes shown in Appendices B-F. For each patient, it assigned a care oriented classification based on the prior probabilities (see Figure 2). The patients were then routed through the appropriate flow chart. Encounters and resource contention were modeled using a series of subroutines described below.

Encounter and Resource Contention. The interaction of a patient with various resources such as physicians, residents, nurses and rooms are modeled in a way to resemble most closely the functioning of the Clinic. From the viewpoint of model development, this was the most challenging and stimulating task. Described here are two examples of such modeling challenges.

Preserving the *identity of relationships* was important for several reasons. Surgical RVs typically visit with the providers they consulted with in their first visit to the BCC. This presented a need for tagging the patients as well as matching them to the appropriate provider in all future visits. The identity of each provider had to be maintained to accomplish this task. A similar matching problem arose in modeling the interaction between residents and physicians since each resident was associated with a specific physician.

Modeling of *logically dependent concurrent events* presented another challenge. Consider, for example, a situation where a patient is waiting for a physician. The physician is currently being briefed by a resident who has already examined this patient. The impending encounter of the physician with the patient cannot commence until this briefing is over. Neither can the patient be seen by other providers. An event link between the resident, physician and patient is required to ensure concurrency.

Data Input. This segment of COSM provides input to the simulation module described by the

Patient Flow Manager and Encounter Resource Contention segments in appropriate format. It serves as an interface between the external world (including other BCC databases) and COSM. Information from the patient flow survey, results of historical analysis, and clinic observations are presented as an input file which is read and interpreted by the Data Input segment. This approach simplifies "what if " analysis by allowing easy and accurate modification of input parameters. It also delineates program logic contained in the previous two segments from potentially evolving information.

Report Generator. This segment of COSM is designed to provide simulation output for performance measures of interest in a user friendly fashion. During the simulation run the Report Generator accumulates statistics of interest such as utilizations for each physician, the patient residence times, and the arrival times of the physicians to the noon conference. It lead the user, who may not be conversant with a simulation language, through a choice of output formats ranging from means to distribution information of specific measures.

Defining in a quantitative manner what a performance measure did or did not constitute was the most difficult part of encoding the Report Generator. For example, it was not easy to arrive at a consensus about which activities should be included in the computation of physician utilization. It was decided to include only those activities which directly contributed to the care of patients in the BCC. These tasks included patient encounters, conferences with residents, and dictation and note taking. An exception was time spent by physicians in the GSC, which was included. Activities such as phone calls and administrative work were not included.

Another example of a performance measure which was difficult to define in an unambiguous manner was the delay in physician arrival at the noon conference. The noon conference would typically start on time. Providers would arrive when they finished their Clinic responsibilities. An option was to report the amount of delay for each late arriving physician. However, the presence of all providers at the conference was so essential to fulfill the mission of the BCC that it was decided to report the time of the last arriving physician. This ensured that each patient case discussed during the conference had input from all disciplines involved and hence ensured the highest quality of care.

The other challenge in encoding the Report Generator was related to the level of detail in which performance measures ought to be reported. This issue was intrinsically linked to the goals of the simulation study and the variety of "what if" analyses that needed to be performed. The relative importance of various factors affecting the Clinic performance was not clear at the onset. For instance, alternative scheduling rules could have different effects on the residence time of RVs and NPs. Therefore, residence times for each patient type was reported separately. Because patients in care-oriented classes had marked differences in care requirements, residence times for different care classes could also experience different changes. To examine this possibility, patient residence times were also reported by care-oriented classes.

4.3 Validation

Validating the simulation model consisted of rigorous comparisons of model output with collected data for all three modules.

Validation of the PLG involved ensuring that the three different case loads were reproduced in a statistically consistent manner. NP and Radiation RV load were compared with the historical data available. For the NP load, the seasonality index and growth trend had to be evaluated, as well as the mean and standard deviation of the load. Validation of the Radiation RV load was stable over time and thus only the mean and spread needed to be established as a true representation. Validation of the Surgical RV load was a difficult task because of the use of a model parameter, RV retention rate, in the PLG. This rate was computed for each surgical oncologist based on their retention history, and was found to be significantly different. However, the physicians were surprised by the differences in RV retention rates among the surgical oncologist. Since the intention of Clinic was to provide identical care, it was decided to use a single RV retention rate. This rate could then be used as a target by all surgical oncologists. Model validation therefore consisted of experimenting with different rates of RV retention and matching the resulting patient loads with the Clinic load.

The patient appointment times assigned by the scheduling rule encoded in the SCM were compared with appointment sheets filled out by the clerks. For case loads that were similar in the real and simulated clinic, the appointments for each patient type, NP, Radiation RV, and Surgical RV, were matched. For any discrepancies found in the appointment times, the scheduling clerks were consulted and if necessary the encoded SCM rule was adjusted.

The validation of COSM was performed by statistically comparing the simulation output on the residence times, waits for providers, and utilizations with those collected from the patient flow survey. Because COSM was written to be understood by those unfamiliar with a programming language, it was possible to corroborate the accuracy of much of the Patient Flow Manger and Encounter and Resource Contention code directly with the physicians and staff of the clinic. This not only enhanced model validation, but also increased the confidence of the physicians and staff in the results of the model.

5 The Development and Evaluation of a New Scheduling System

The simulation model was used to evaluate a new scheduling procedure based on care requirements for the patients. According to the care oriented classifications patients could be described in terms of whether they required interdisciplinary care (ID) or not (NID). Several factors highlighted the importance of ID patient care at the BCC. First of all, the mission of the Clinic was to treat patients requiring interdisciplinary care. Secondly, the required service time of ID care was significantly larger than NID care. Therefore the ID patients had less flexibility in how they were scheduled. Also, great care had to be taken in scheduling the ID patients because of the cascading effect caused by delays in early encounters between ID patients and the physicians. In contrast, NID patients required a single visit and thus could be scheduled around the physician requirements for the ID patients. These ideas were exploited in creating the new scheduling rule.

To minimize delays to physician arrival at the noon conference, ID patients were scheduled early in the day (See Figure 5). The time between successive appointments corresponded to the service time of their first encounter with the surgical oncologist. Following the encounter with a surgical oncologist, an ID patient would need to see a radiation oncologist and then a internal medicine oncologist to get a complete diagnosis. Surgical oncologists would thus be available to provide

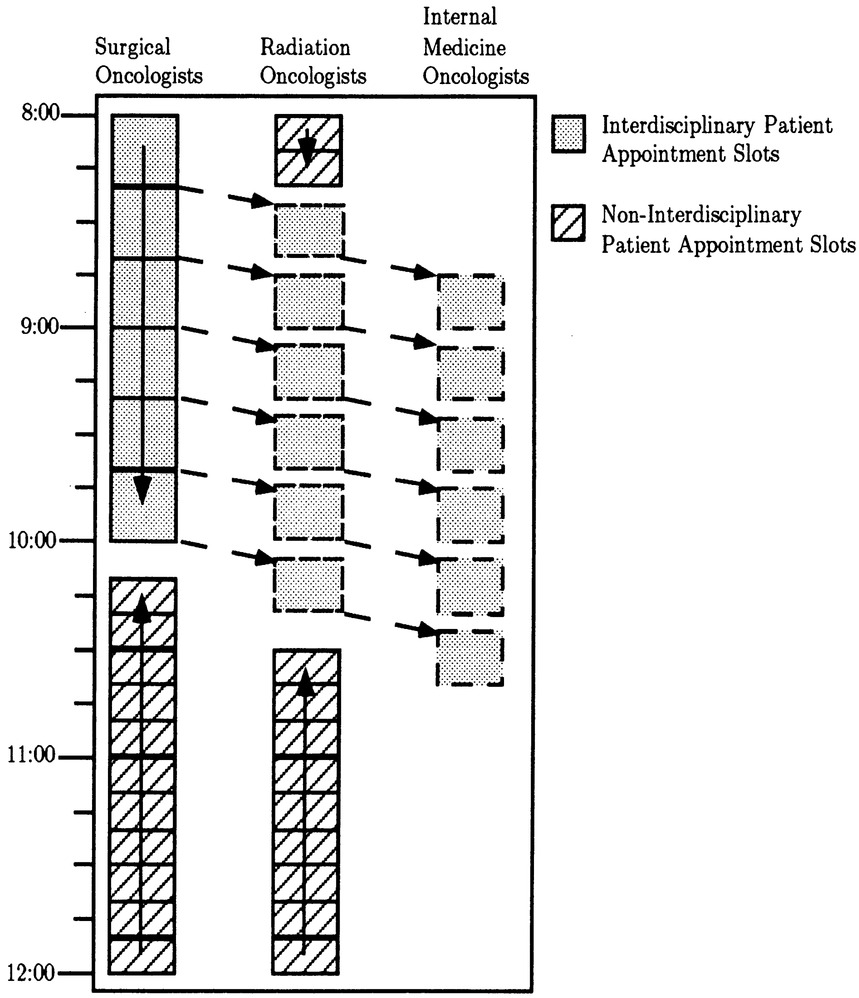

Figure 5: The Improved Scheduling Template

care to NID patients after the ID patients. Because ID patients are mostly new patients, they seek appointments close to the date of the clinic. Due to the variability in new patient load, it is important to leave as much time for them as possible. Therefore, the scheduling rule assigns appointment times to the NID patients in reverse order from the end of the Clinic. This new rule for scheduling is known as the "Forward/Backward" rule. Because radiation oncologists see the ID patients after the surgical oncologists and prior to the internal medicine oncologists, there is time available in the early and late stages of the Clinic for Radiation RVs. The encounter pattern of the radiation oncologist with ID patients is identical to that of the surgical oncologist except for a small time shift. This time shift is equal to the time taken by the surgical oncologist to see the first ID patient. The first few Radiation RVs should be scheduled during the time shift.

The rest of the Radiation RVs should be filled from the end in a backward fashion. Finally, the encounter pattern of the internal medicine oncologist with ID patients is identical to that of the radiation oncologist except a long time shift due to the encounter of the first patient with surgical and radiation oncologist. Because the internal medicine oncologists have no return visit patients in the BCC, they are not needed until the first ID patient is available. Since this scheduling method clarified the inter-relationships among providers, and the need to start the schedule with ID patients, nursing staff were more strict in admitting the patients according to the schedule pattern, not the arrival pattern.

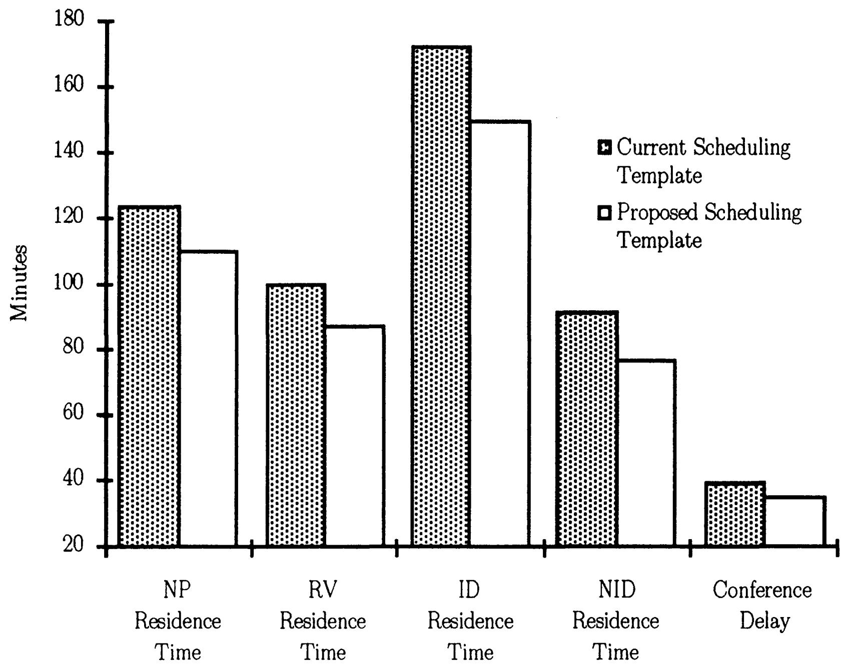

Figure 6: A Comparison of the Proposed versus Current Schedule

The simulation model was used to evaluate the impact of the new scheduling rule on the performance of the Clinic. Figure 6 shows the patient residence times and physician arrival at the noon conference under both the current and proposed scheduling rules. The residence times for both RVs and NPs were decreased almost the same amount. However, interdisciplinary patients had a more significant drop in residence time than non-interdisciplinary patients. This difference highlights the focus of the new schedule on interdisciplinary patients. The delay of physician arrival to the noon conference decreased although not significantly. This suggests that the clinic load is too high.

6 Patient Load Smoothing

The simulation model was also used to analyze the effects of changing patient loads, and to determine an efficient mix of patients. As previously discussed, the only way to smooth the load of the Clinic was to restrict the number of return visits. Restrictions could be placed on the number of Surgical and Radiation RVs. This section first examines the impact of limiting the Surgical RVs and concludes with an analysis of the effect of Radiation RV load.

Two constraints were used to limit the number of Surgical RVs. The first constraint placed a limit on the maximum number of Surgical RVs scheduled for any BCC session. Using the historical distribution of NP arrivals, the model was used to determined the maximum number of return visits that could be scheduled for the surgical oncologist without delaying their arrival to the noon conference. Because of the variability in service times, patient care requirements, and NP load, this number did not guarantee on time arrival of the surgical oncologists at the noon conference. However, multiple runs of the model indicated that the limit was successful 95% of the time. This limit was adjusted to account for the seasonal variation. In addition, because the NP load was growing, the number of Surgical RVs would have to be decreased over time.

The second constraint was needed to limit the rate of RV retention. Because of the cap on the number of RVs, if the rate of RV retention was large, scheduling delays would grow without bound. The propensity of a physician to ask a patient to return to the BCC depended on whether a patient was an NP or an RV. 90% of all NPs returned to the clinic as an RV for a follow up session. While the first return visit was considered crucial for follow up care, the reasons for subsequent visits were not as compelling. After a few visits, RVs could be referred to outpatient care centers, or could be rescheduling them at other times during the week. Several factors were contributing to the high level, and potential increase of Surgical RVs. Long term study of recovery from breast cancer was made possible by such visits. Often the close doctor–patient relationship developed in life or death situation, and the fear of relapse made patients return to the Clinic. In some cases, complications or relapses forced patients to return for a series of visits.

The complexity of this issue suggested that the Clinic needed to reexamine its responsibilities and mission which emphasized providing care to the new patients. It was clear that in order to provide a sufficient quality of care to the new patients, the Surgical RV patient load had to be limited. However, to suggest a reduction in RV retention, it was essential to have a clear understanding of the effect it had on the clinic operations. It was also important to understand how RV retention affected the ability of the Clinic to schedule the RV appointments in a timely fashion. Understanding the tradeoffs between these various influences would enable the management to determine an appropriate policy. It should be noted that limiting RV retention does not necessarily translate into a fixed number of revisits for each patient. Rather, it implies that on an average, the percentage of people recommended for revisits should be limited.

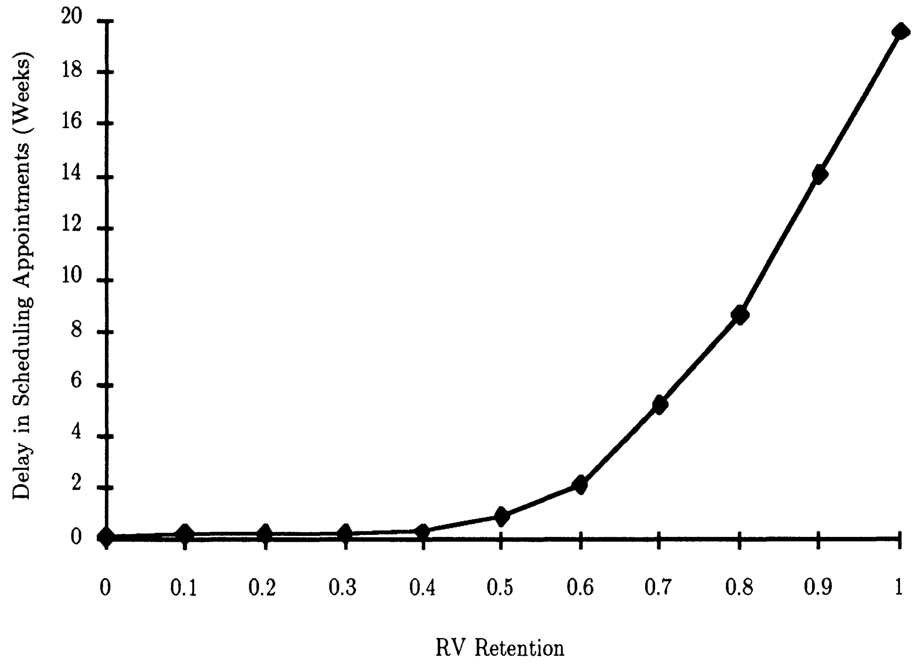

Figure 7: The effect of RV retention on scheduling delays

Output from the SCM described how the RV retention affected the average delay in requested versus scheduled RV appointments. COSM could then determine how an increased RV retention rate affected physician utilization, delay in physician arrival at the noon conference, and patient residence time in the clinic. Figure 7 shows the average number of weeks that appointments are delayed as a function of the RV retention. The plot clearly indicates a slow and linear increase in scheduling delay as a function of RV retention. However, after a point, the delay in scheduling increases disproportionally with RV retention and finally acquires an exponential growth pattern. This *knee* effect is typical of growth in scheduling delay as a function of RV retention for any clinic with return visits. The critical RV retention rate in this case was found to be approximately 60%. In general, the critical RV retention rate is a function of the number of providers, other resources, care time, total length of clinic and other operating parameters.

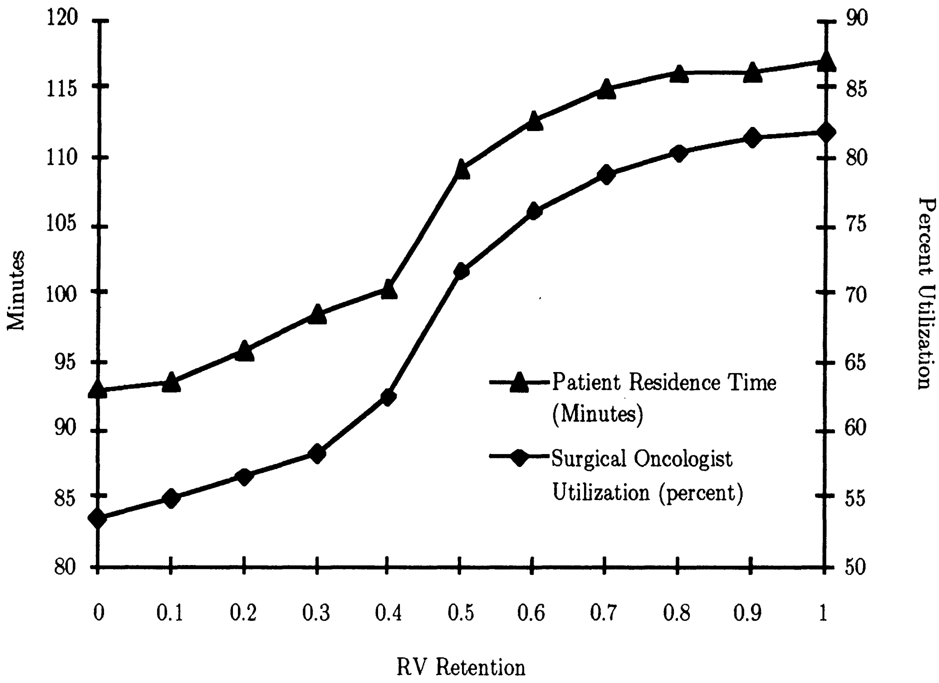

Figure 8: The effect of RV retention on Residence Time for Patients and Utilization of Surgical Oncologists

Patient residence time and surgical oncologist utilization increase with an increase in the rate of RV retention as shown in Figure 8. Note however that both these quantities are far more sensitive to increases in RV retention initially. After a point any further increase in RV retention has little impact on the patient residence time or surgical oncologist utilization. Because of the limit placed on the maximum number of RVs allowed in any session, extra RVs simply get transferred to future sessions, (see the delay in scheduling Figure 7), instead of overloading.

The conference delay is affected both by RV retention and Radiation RV load. For a given value of Radiation RV load, conference delay increases as RV retention increases (see Figure 9).

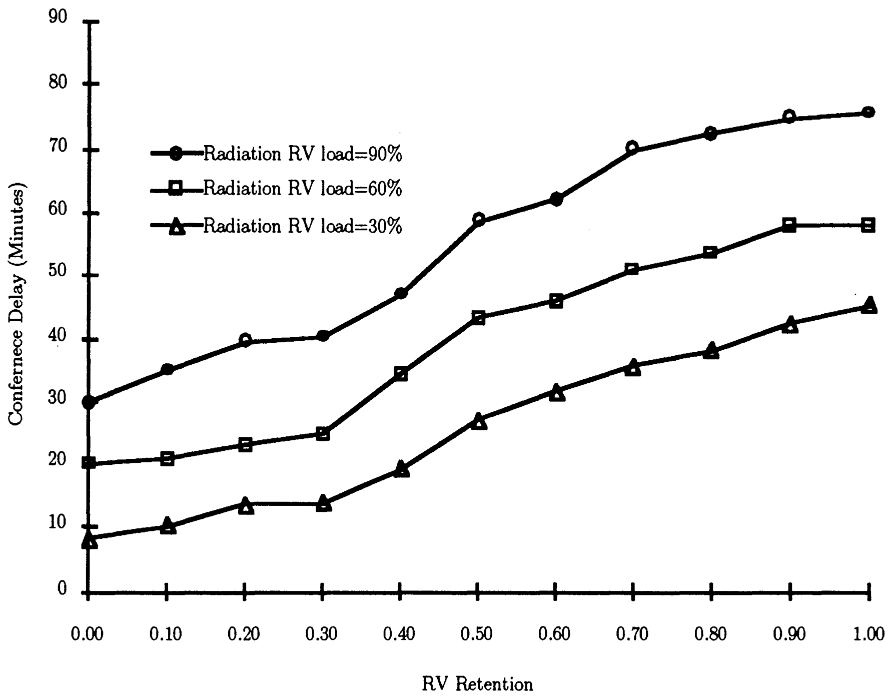

Figure 9: The Effect of RV Retention on Conference Delay

However, the rate of increase decreases and the conference delay saturates for high RV retention. This is again because of the limit placed on the maximum number of RVs allowed in any session. An increase in the Radiation RV load increases the conference delay for a particular RV retention as shown in Figure 10. Note however that the conference delay increases at an increasing rate with Radiation RV load. To reduce the conference delay, it is critical to reduce both RV retention and Radiation RV load.

7 Implementation, Obstacles and Improvements

The hospital administration maintained a keen interest during the entire project. Various staff were also very cooperative. Getting providers to complete the survey form regularly was a difficult and sensitive issue. They were unsure what the date was to be used for and whether it would have any impact on the Clinic operation. However, the promise to maintain confidentiality together with a discussion of operational issues convinced them of the merit of such a study.

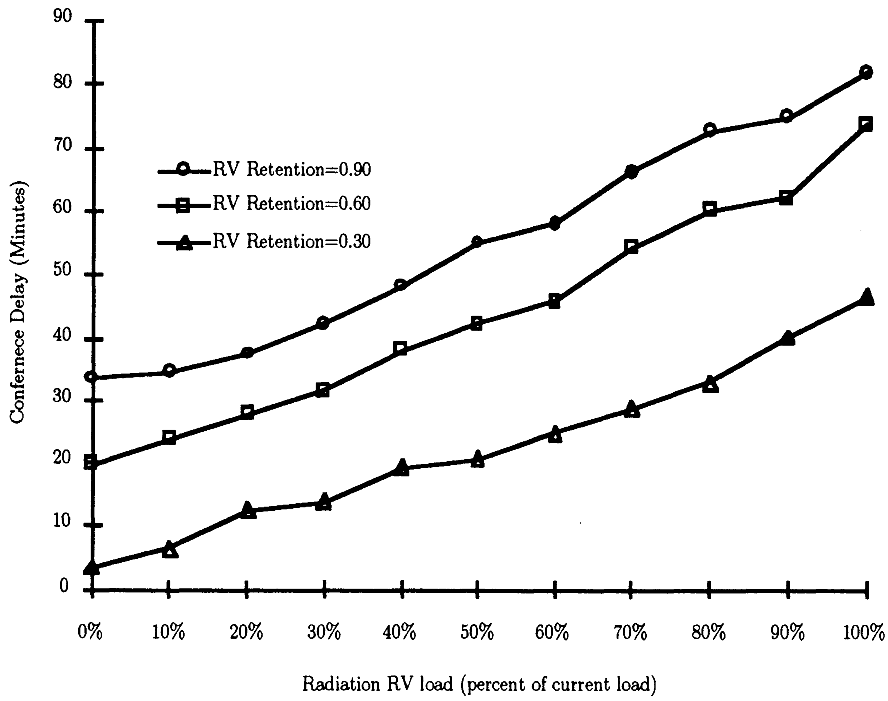

Figure 10: The Effect of Radiation RV Load on Conference Delay

We spent significantly more time and effort in understanding the Clinic operation and collecting data than in the development of the simulation model. Defining the measures of Clinic performance was not an easy task. While everybody agreed that providing high quality care was the fundamental goal of the Clinic, there was no consensus on how to measure this quality. This issue became particularly important when the Clinic had to choose between conflicting quality goals. Monitoring recovered patients over a longer time was viewed as important by many physicians to avoid potential complications. However, the resulting RV load increase lead to longer patient residence time and delayed the physicians arrival to the noon conference. Similar conflicts could be found between the Clinics long term goals of higher revenue by bringing in more patients and its adherence to a consistently high quality of patient care. The simulation study clarified the tradeoffs available between many of these conflicting objectives.

An interesting outcome of the data collection effort was that it made the various constituents of the Clinic aware of the interdependencies of their activities. For example, many physicians were somewhat aware of the cascading effect of the service requirements of the interdisciplinary patients.

They were not aware, however, of the extent to which their occasional long encounter affected the arrival of other physicians at the noon conference. The effect of the conflicting schedule between the BCC and the General Surgery Clinic also became clear form this study. The simulation model was able to demonstrate the benefits of coordination between the two clinics.

The simulation study itself contributed not only a new set of operating procedures for the clinic, but also provided a new paradigm for clinic operation. The direct benefits of the simulation study in terms of procedural and performance improvements include:

- prompt arrival of physicians to the noon conference
- a decrease in clinic residence time for patients
- an improved scheduling mechanism based on patient service requirements, and
- guidelines for load smoothing based on realistic capacity planning

In our continuing effort to improve Clinic performance, the tradeoffs between other resource constraints (i.e. rooms, physicians, and staff) and their impact on Clinic performance is being evaluated. The increasing success of the BCC has made it a model for interdisciplinary care. This simulation study will benefit other interdisciplinary care units as well by providing an understanding of interdependencies among care providers. The flexibility of the simulation model will allow modeling of other interdisciplinary units without significant effort.

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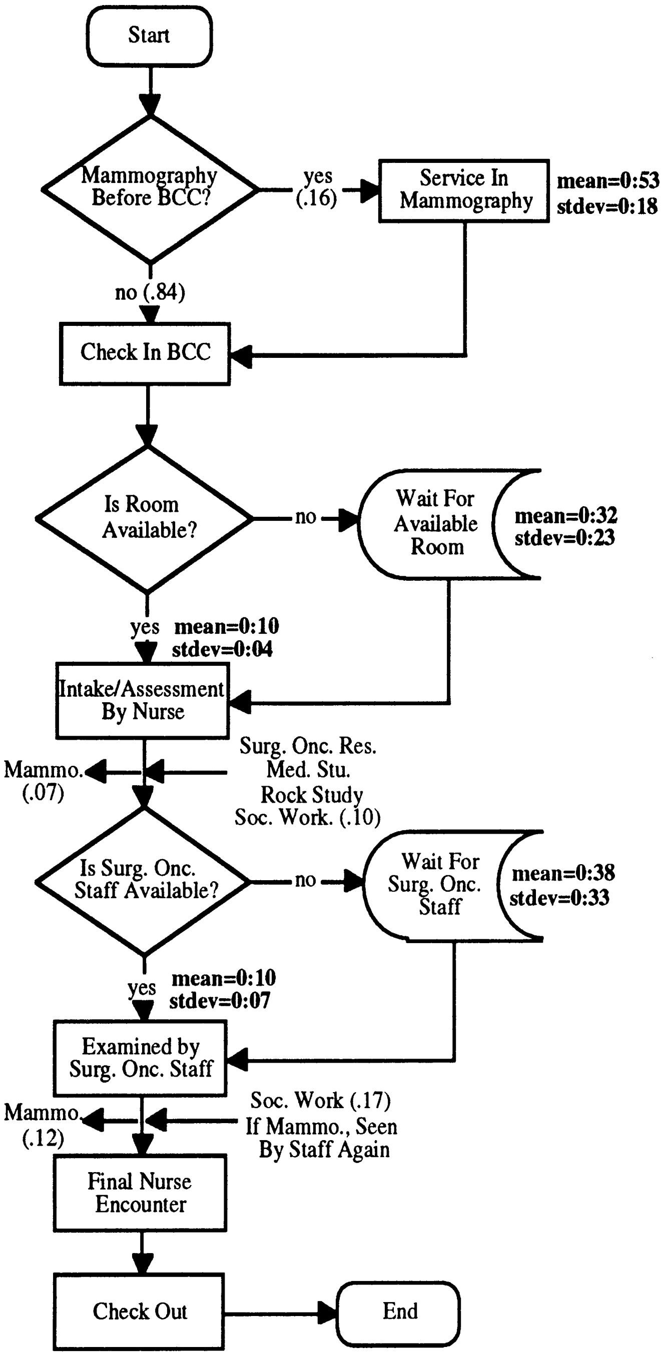
A Breast Care Clinic Patient Flow Survey Form

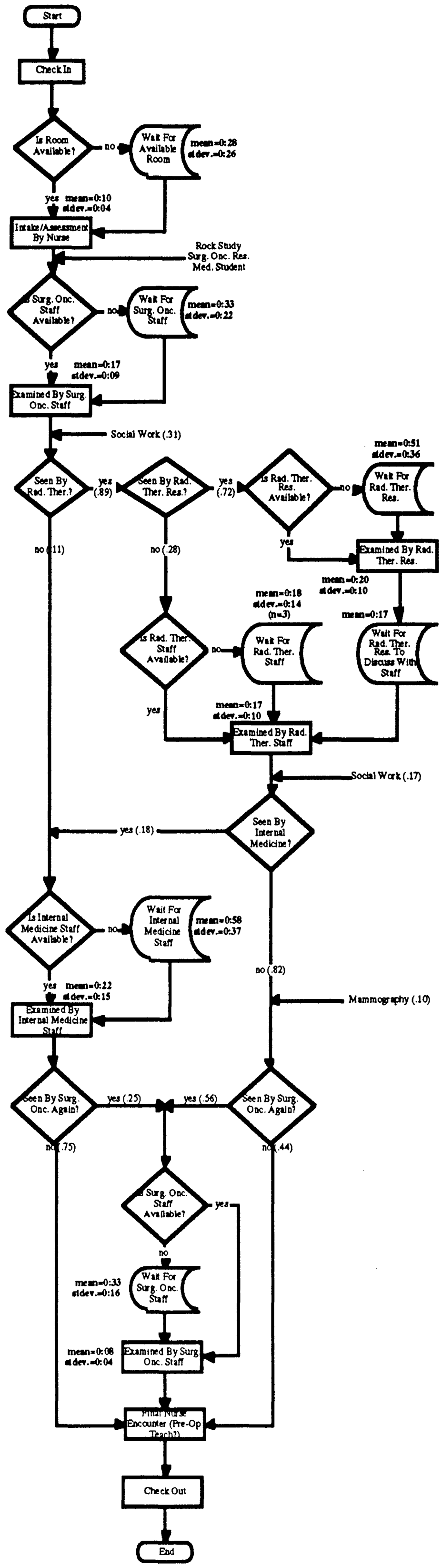
Comments:	Registration Card:
* Definition of Encounter: Any face to face meeting between provider and patient. A physical separation of 2 or more minutes is another encounter. Patient Type: NP RV Assigned Physician:	

Room #	Provider		Name	Start Time	End Time	Activity
	Surg Onc Rad Onc Int. Med. Mammo. Staff M.D. Resident Med Student	Nurse Soc. Wrk. Tech Volt. Clerk Other				BSE Teaching Biopsy Pre-Op Teach Other
	Surg Onc Rad Onc Int. Med. Mammo. Staff M.D. Resident Med Student	Nurse Soc. Wrk. Tech Volt. Clerk Other				BSE Teaching Biopsy Pre-Op Teach Other
	Surg Onc Rad Onc Int. Med. Mammo. Staff M.D. Resident Med Student	Nurse Soc. Wrk. Tech Volt. Clerk Other				BSE Teaching Biopsy Pre-Op Teach Other
	Surg Onc Rad Onc Int. Med. Mammo. Staff M.D. Resident Med Student	Nurse Soc. Wrk. Tech Volt. Clerk Other				BSE Teaching Biopsy Pre-Op Teach Other
	Surg Onc Rad Onc Int. Med. Mammo. Staff M.D. Resident Med Student	Nurse Soc. Wrk. Tech Volt. Clerk Other				BSE Teaching Biopsy Pre-Op Teach Other
	Surg Onc Rad Onc Int. Med. Mammo. Staff M.D. Resident Med Student	Nurse Soc. Wrk. Tech Volt. Clerk Other				BSE Teaching Biopsy Pre-Op Teach Other
	Surg Onc Rad Onc Int. Med. Mammo. Staff M.D. Resident Med Student	Nurse Soc. Wrk. Tech Volt. Clerk Other				BSE Teaching Biopsy Pre-Op Teach Other
	Surg Onc Rad Onc Int. Med. Mammo. Staff M.D. Resident Med Student	Nurse Soc. Wrk. Tech Volt. Clerk Other				BSE Teaching Biopsy Pre-Op Teach Other
	Surg Onc Rad Onc Int. Med. Mammo. Staff M.D. Resident Med Student	Nurse Soc. Wrk. Tech Volt. Clerk Other				BSE Teaching Biopsy Pre-Op Teach Other
	Surg Onc Rad Onc Int. Med. Mammo. Staff M.D. Resident Med Student	Nurse Soc. Wrk. Tech Volt. Clerk Other				BSE Teaching Biopsy Pre-Op Teach Other
	Surg Onc Rad Onc Int. Med. Mammo. Staff M.D. Resident Med Student	Nurse Soc. Wrk. Tech Volt. Clerk Other				BSE Teaching Biopsy Pre-Op Teach Other

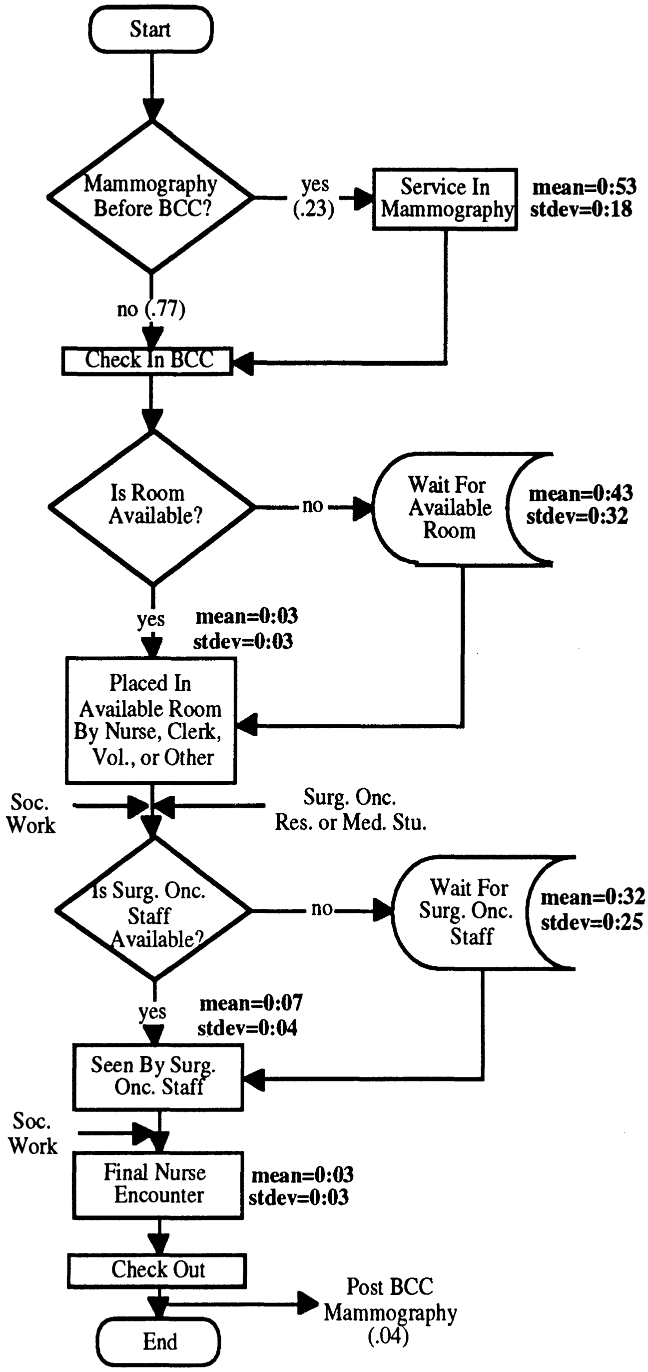
B New Patient Non Interdisciplinary Flow Chart



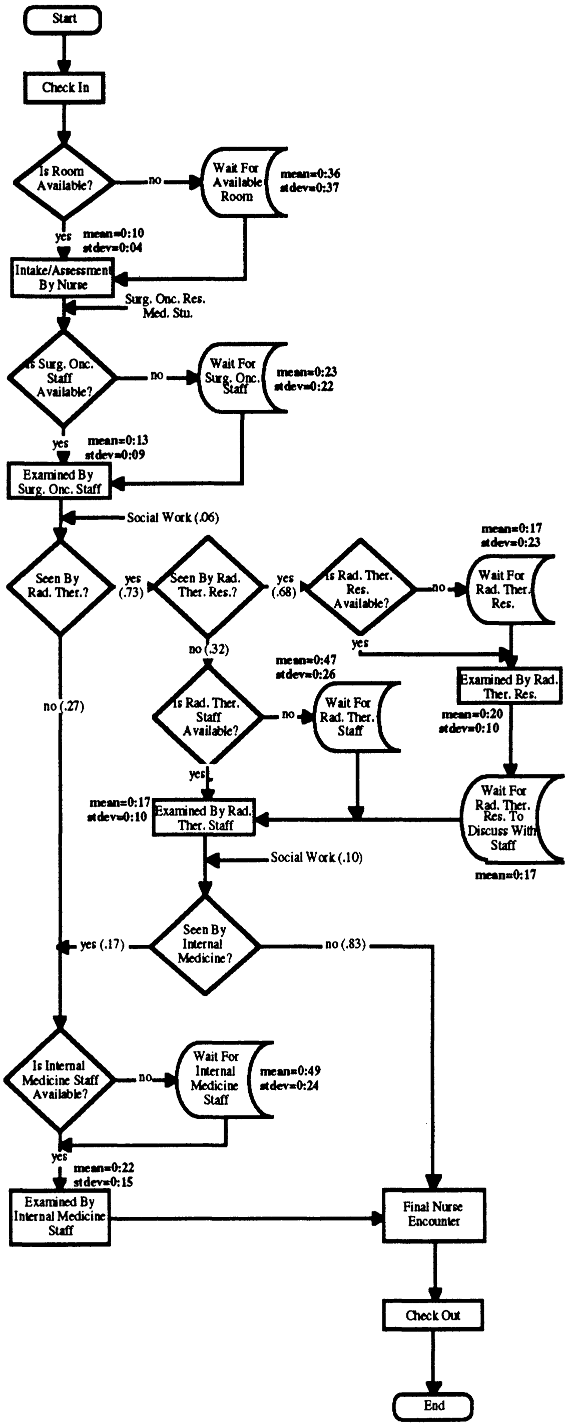
C New Patient Interdisciplinary Flow Chart



D Surgical Oncologist Return Visit Non Interdisciplinary Flow Chart



E Surgical Oncologist Return Visit Interdisciplinary Flow Chart



F Radiation Oncologist Return Visit Flow Chart