Reducing Patient Wait Times and Improving Resource Utilization at BCCA’s Ambulatory Care Unit through Simulation

Pablo Santibáñez1 • Vincent Chow1 • John French1 • Martin Puterman2 • Scott Tyldesley1
1. British Columbia Cancer Agency, Vancouver, Canada
2. Sauder School of Business, University of British Columbia, Vancouver, Canada

Abstract
Variable patient volumes, limited capacity, and an inflexible physical layout in the Ambulatory Care Unit (ACU) at the British Columbia Cancer Agency’s Vancouver Centre led to a process review of this unit. To provide a framework for studying recommendations we developed a computer simulation model of the ACU. We used it to evaluate the impact of changes to physical configuration, scheduling policies, capacity allocation, and other dimensions that affect patient wait time, clinic overtime, and resource utilization. Through scenario analyses we found that the best outcomes were obtained when not one but multiple changes were implemented simultaneously. We developed configurations that achieve a reduction of up to 70% in patient wait times and 25% in physical space requirements, for the same appointment volume.

The key recommendations from the study are: redistribute clinic workload more evenly across the week and time of day; allocate examination rooms more flexibly and dynamically among individual clinics within each of the oncology programs; promote clinic punctuality; and re-evaluate scheduling practices. These recommendations are currently being evaluated for implementation by senior management.

1. Introduction
The British Columbia Cancer Agency (BCCA) provides a province-wide, population-based cancer control program for the residents of British Columbia and the Yukon, Canada. The Vancouver Centre (VC), where we conducted this study, is the largest of the 5 BCCA regional cancer centres, and is the referral facility for several subspecialized provincial radiotherapy programs.

Within each regional centre, the Ambulatory Care Unit (ACU) is the area designed to deliver care and services to non-hospitalized patients on an outpatient basis. Under BCCA’s model of care, the ACU is the primary point for physician-patient contact. All three cancer programs (medical oncology, radiation oncology and surgical oncology) conduct patient appointments within the ACU. These include new patient, follow-up or interprogram consult appointments.

ACU appointments often involve multiple physicians, including oncologists, residents and medical students, in addition to other clinicians (including nurses, dieticians and counsellors). We use the term physician throughout this paper to refer to any interaction with either an oncologist, a resident, or a medical student. When the interaction refers specifically to the oncologist, resident or student in particular, we have stated as such.

The ACU also serves as an academic teaching and research environment. There continues to be an increase in the number of medical students, residents and fellows within this environment, as well as students and interns from other disciplines such as nursing. In addition there are an increased number of patients enrolled in Clinical Trials, which results in increased requirements for space and staff.

VC has a larger patient volume and academic and research duties than other BCCA centres; this may limit the generalizability of this study to less academic centres. In 2007/08, about 41% of the total 14,051 provincial cases treated by BCCA received care in the VC. The ACU experienced an average of 200 patient visits per day during the same period.

The motivation for this study grew out of the significant, increasing challenges regarding the use of space and resources experienced at the VC’s ACU during the last few years. Physicians’ office space,
clerical support and examination rooms were often in short supply at times of peak volume. This led to overcrowding, delays, and concerns regarding safety of critical patient care duties undertaken within the ACU.

The existing ACU configuration was based on historical designs which pre-date the extensive use of information technology, and growing patient volumes and academic and teaching activities, and hence did not match existing space or operational models at newer centres. In addition, changes to practice, such as the electronic chart, direct order entry and tele-health initiatives required modifications to the functional aspects and hence space requirements of the ACU.

To address these issues, in December 2007 BCCA initiated an operational review of the ACU processes, centred on a data-driven, evidence-based approach and supported by operations research methodologies. The purpose of this review was to provide advice on operational aspects of VC’s ACU, with a focus on the following aspects:

- Physical space: size, number and configuration of examination rooms, physicians’ workspace and patients’ waiting area.
- Operations: physician schedules, separation of programs, booking practices, models of care, staffing levels.

2. ACU Process and Clinics

Figure 1 depicts the patient journey in the ACU during a typical appointment. Although variations occur depending on the needs of the patients, the typical appointment process in the ACU can be described by the following steps:

a) The patient arrives to the ACU and checks in at the reception. This event is recorded in the booking system and is visible to nurses and physicians through the information systems.

b) The patient goes to the waiting room and remains there until called.

c) A nurse or volunteer takes the patient into an examination room, fills in basic information such as weight and overall status in the patient record, and then leaves the chart in the physician office.

d) The patient waits in the room for the physician(s).

e) The physicians (student/resident/oncologist) come into the room. There could be multiple patient-physician interactions.

f) For multiple consults, the patient waits for the next physician to arrive, the subsequent consults take place, and then the patient exits the room.

g) When patients are required to wait for future appointments to be booked or additional services, they go back to the waiting area before being dismissed. Physicians go to their office to dictate and prepare orders for future appointments and tests, which then go to the nursing station to be processed. After orders are completed, a nurse sees the patient, hands over the appointment card and discharges the patient from the ACU. Further nursing activities including patient education and medication injections may subsequently take place in nursing assessment rooms.

Patients may also have other appointments in the cancer centre before and/or after the ACU consult. Usually blood and imaging tests are required before seeing the physician. Backlogs in other departments may interfere with the ACU process by delaying the arrival of the patients (or their corresponding test results).

On a typical day in the VC, among the three oncology programs there are between 15 and 25 different clinics running simultaneously. Each clinic is run by a different oncologist, and may also include the participation of other physicians such as a medical student, a resident, or a fellow. The configuration of these clinics, in terms of the number of physicians involved and the number and type of patients that are scheduled, varies on a daily basis. In general, clinics have regular scheduled hours every week with pre-defined appointment slots for different patient types. Variations to the schedules occur when physicians are away or in case of urgent cases.

Clinics from each of the three oncology programs function in separate although adjacent areas in the ACU. Every program has its own set of

Figure 1: Patient process for an ACU appointment
examination rooms, a nursing station and clerical staff. There are 45 examination rooms in total: 24 are allocated to the medical oncology program, 16 to radiation oncology, and 5 to surgical oncology. The space is organized in pods, usually consisting of 5 examination rooms and one physician room. Figure 2 depicts the existing ACU floor plan.

Everyday ACU managers distribute the available examination rooms among the clinics scheduled to run. They do this one day in advance, based on the total number of clinics and physicians functioning that day, the volume and type of patients in each individual clinic, and staff availability.

As a general rule, each clinic gets two examination rooms. This allows for a very efficient use of the physician’s time as it avoids situations where they are forced to wait for the next patient because of room/patient unavailability (i.e., due to room turn-around and/or patient preparation times). In the simplified case of one physician and no turn-around times, two rooms allow the physician to go without interruptions from one patient to the next—assuming patients are placed and prepared in the rooms in a timely manner. If a clinic has the oncologist plus another physician, then two rooms might not be enough, especially if they operate in parallel. A similar situation occurs when patient-preparation times are considerable and there are several, short-duration appointments scheduled in a clinic, resulting in physicians being idle between patients (we should note that being idle is with respect to direct patient care; physician idle time may still include activities such as medical student teaching, responding to emails or pages, phone calls, or editing electronic patient reports, etc.). Conversely, clinics with one physician, fewer patients and longer appointments may not need more than one examination room.

The configuration of rooms into pods is to some extent restrictive, in that coordination becomes more difficult if a physician is assigned two rooms in different pods. In practice, ACU managers try to assign physicians examination rooms located in the same pod.

As a result, the allocation of examination rooms to clinics has the potential to cause delays for patients or excessive idle time for physicians. The right balance depends on the total patient workload and resources available in the entire ACU.

3. Analysis and Model
3.1 Preliminary Data Analysis
To identify bottlenecks in the ACU process and quantify their impact, we performed comprehensive process and data analyses. Patient volumes and resource utilization for the Vancouver Centre were compared to another BCCA centre in the Lower Mainland (Fraser Valley Centre). This provided a starting point to identify potential areas of improvement.

The primary data sources for the data analysis included the appointment booking system and its data warehouse. These databases have scheduled appointment information for all patient visits, in particular those to the ACU. Patient volumes by time of the day, day of the week, and month were analyzed at different levels: overall ACU, by program (medical, radiation and surgical oncology), by visit type (new patients, follow-ups, consults) and by tumour site clinic (e.g., breast, lung, etc.).

Our analysis of the data resulted in the following findings:
- Space availability: VC’s ACU size and configuration is not in alignment with modern

![Figure 2: Floor plan of VC’s ACU and areas by oncology program](image)
design standards. This becomes evident when compared to BCCA’s most recent facility, the Abbotsford Centre. This centre, with significantly reduced academic and teaching duties compared to those at the VC, has significantly larger examination rooms (11m² compared to 8.2 m²). It also has a more functional layout that considers flexible examination room space, smaller and more private patient waiting areas, and centrally located physician space.

- Increasing patient volumes: Over the last 5 years, VC’s ACU has experienced a 9% annual increase in the average number of appointments per day. This is almost twice the growth rate experienced by the Fraser Valley Centre (FVC) in the same period.

- Unbalanced workload: Appointment data (Table 1) show an uneven pattern in daily patient volume, with a peak on Mondays (24% higher than the daily average) and a minimum on Fridays (37% fewer appointments than the average). This pattern seems to be specific to the VC, as the FVC showed a smoother patient workload across the week.

<table>
<thead>
<tr>
<th>Average ACU Appointments - 2007/08</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mon</strong></td>
</tr>
<tr>
<td>AM Clinic</td>
</tr>
<tr>
<td>PM Clinic</td>
</tr>
</tbody>
</table>

Table 1: Average number of appointments per day of the week

Appointment data and the clinics’ records confirm that this is the result of current physicians’ schedules, which have planned reductions in the number of clinics and patient workload on Fridays to accommodate other activities, such as patient conferences or administrative duties.

A direct consequence of peaks in workload is the impact on staff and examination room availability. During high utilization periods, patient volumes and related activities rise, resulting in increasing stress on support personnel (nurses, clerks, and other staff), and escalating the need for resources such as examination rooms. An opportunity exists to better utilize available capacity by distributing workload more evenly throughout the week and time of the day.

Unfortunately, but not at all an unusual situation in health care, available data were not sufficient to determine process and wait times for all the stages shown in Figure 1. Existing information systems record only booking data for appointments. They exclude more detailed information on the processes, such as time stamps for arrival and physician-patient interaction, and performance metrics of the system such as delays, idle time, overtime and room occupancy.

Considering the limitations of the existing data, it was apparent that a time study was required to obtain more detailed data.

### 3.2 Time Study

The objective of this data collection study was to obtain the necessary information to measure patient wait times, appointment duration, and utilization of resources such as examination room and physicians.

We first developed a high-level process map (Figure 3) of the appointment visits and indentified the key points in time we needed to measure based on our observations and experience with the clinic processes. We then used these points to design the data collection process, determining how many surveyors would be required and where in the floor they should be located. We sampled and observed
a number of ACU clinics during the course of several days, capturing process times for over 600 patient visits. We believe this data is unique and provides considerable insight to the patient experience and resource utilization.

Using the collected data we reconstructed the different stages in the ACU process for each patient. We also linked the data to the booking system to append appointment information such as patients’ cancer site, type of visit and appointment time to the process-data.

With all this information, we summarized patient arrivals, physician-patient interaction processes, chart/order processing and turn-around times by program and visit type. We classified each stage as either value-added or non-value-added components. Every stage in Figure 1 involving pure waiting was classified as non-value-added, or ‘waste’ under the lean philosophy (stages b, d, f1 and g).

The analysis of the collected data shows that:

- Most patients arrive on time to their ACU appointments (78% check-in before the scheduled time; only 10% arrive later than 10 minutes), and about 6% of patients miss their appointments (fail to show).
- Patients wait on average 14 minutes from their scheduled appointed time until they are first seen by a physician in the examination room. About 10% of patients wait more than 44 minutes.
- When a resident or medical student is involved, total direct physician-patient interaction time nearly doubles, significantly extending room utilization.
- For some appointments, booked durations differ significantly from the time required for the entire visit. Underestimated appointment durations result in delays for the clinic, while overestimates cause physician idle time.
- Half of the sampled ACU clinics started more than 7 minutes late, with about 10% being more than 23 minutes late.
- On average during a day, 60% of the ACU examination rooms are empty. In the remaining 40%, both a patient and a physician were in the room only half of the time—the other half of the time, only the patient was in the room. Figure 4 shows a typical pattern of examination room utilization by patients and physicians.

The collected data provided great insight about the process, and helped identify areas to explore for opportunities for improvement. Excessive process times (especially for non value-added stages) and low resource utilization served as indications on where to focus our analyses.

In particular, patient wait time data proved very valuable. Physicians and staff had an impression of what patients experience in the ACU, but because they are only involved in parts of the process, it is an imperfect, subjective perception. This new data set provided enough information to build statistical distributions of process and wait times for all the stages in the ACU process. It also produced an understanding of what patients experience ‘on average,’ what the worst case scenario (depicted by the 90th percentile) looks like and how frequently it occurs.

We shared our data analysis results with physicians and other ACU personnel, to validate our understanding and interpretations of the process, and to gather additional input not reflected in the data that could help us redesign operations.

3.3 Literature Review
Based on the preliminary findings from the analysis of both booking and collected data, we decided to explore changes in the following areas:

- Booking and scheduling practices
- Patient and physician interaction
- Examination room allocation

Because processes and changes in the proposed areas were difficult to replicate using traditional data analysis, we decided to develop a computer simulation model of the entire ACU.

There are numerous studies that use simulation modelling to address a broad range of problems in health care settings. Jun et al. (1999) survey the application of discrete-event simulation modeling to health care clinics and systems of clinics. In particular, the body of literature on outpatient (or ambulatory) studies is significant, with special emphasis on appointment scheduling. Bailey (1952) reports one of the first studies on scheduling appointment rules. Cayirli and Veral (2003) provide...
a comprehensive review of the literature on this particular aspect.

In early studies physician time was considered more valuable than patient time. Thus, the main objective was to make the most efficient use of the physician’s time, scheduling patients to reduce idle time, usually at the expense of an increase in patient’s wait time. More recently, patient time has gained more importance, pushing for a more balanced solution.

The majority of the published work is empirical research applied to a specific case. Therefore, conclusions cannot be directly generalized to other situations involving different settings, such as other arrival patterns or appointment durations.

There are some examples specific to cancer care. Among others, Sepúlveda et al. (1999) report their work at M. D. Anderson Cancer Center in Orlando, FL, a full-service cancer treatment center. Their objective was to analyze patient flow throughout the unit, evaluate the impact of alternative floor layouts, using different scheduling options, and analyze resource and patient-flow requirements for a new building. Baesler and Sepúlveda (2001) present a case study with a simulation model integrated to a multi-objective optimization heuristic to find the best combination of control variables, considering four performance measures for a cancer treatment center facility. More recently, Matta and Patterson (2007) address the problem of evaluating multiple performance measures in simulation experiments of outpatients clinics, a research motivated by The Division of Medical Oncology at the Duke University Medical Center (DUMC).

In addition to the pressing needs for additional space in the ACU, this study was motivated by the importance of providing timely access to health care services. Especially in services that involve high levels of distress for patients, such as cancer care, reducing unnecessary wait times seems important.

In parallel, the need for health care institutions to meet recently established service delivery standards, such as wait times for surgical procedures or to start treatment, requires increased operational efficiencies. There exists evidence in the medical literature supporting a relationship between increased waiting time to start treatment and inferior clinical outcomes for radiotherapy (Mackillop, 2007; Chen et al., 2007). In these efforts to improve resource utilization, studies such as ours contribute to use existing capacity efficiently.

A large number of simulation studies in health care settings report on the difficulty of obtaining the required data to support modelling efforts such as this one, similar to the situation we faced. White (2005) review data sources used in simulation studies in health care and suggest alternative sources of data. Isken et al. (2005) describe an approach for data collection using sensor networks in health care clinics, and Takakuwa and Katagiri (2007) report on a simulation study developed using a series of data from terminal units and of test/inspection terminals as well as electronic medical records.

3.4 Simulation Model

Considering the characteristics of the ACU process, we decided to use discrete event simulation, and developed a model using the Rockwell Arena (version 11) software.

The model encompasses patient flow from arrival to departure from the examination room, seizing limiting resources such as oncologists and examination rooms. It incorporates the randomness and variability present in all stages of the process, including patient arrivals, consult durations, and process times.

The complexity of the process dramatically increases when all clinics are considered simultaneously. It is very difficult to visualize the operations of 15 to 25 clinics from all oncology programs, some with multiple physicians, using up to 45 examination rooms.

A significant difference between our model and those reported in the literature is the consideration of multiple clinics operating simultaneously. This better represents the real process, especially when considering resources that are shared among several clinics, such as examination rooms and waiting area.

Another important difference is the inclusion of more than one physician (residents and medical students in addition to oncologists) as part of the process. This is very relevant in an academic environment, such as the one studied in this paper, because overall process times and resource requirements increase due to the additional physician-patient interactions.

The model captures both variable patient arrival and clinic start times. We generated patient arrivals to the ACU using past appointment schedules. To mimic actual arrivals with variability in patient punctuality, we adjusted the scheduled arrivals according to a random distribution derived from data collection. This distribution contains the time difference between scheduled patient time and actual patient arrival. Factoring in this distribution into patient arrivals creates arrival patterns similar to those observed in reality. Physician availability at the beginning of the clinics is modeled in a similar fashion to reflect variable clinic start times.

A majority of the queuing that occurs within this system follows a “first-in, first-out” rule. The
assignment and placement of patients in the examination rooms is slightly more complex. Patients first queue for a room before queuing for a physician. Because of variability, patients may arrive substantially earlier than their scheduled appointment time. In some cases, they can arrive earlier than the patient booked before, in which case they are forced to wait until the previous patient’s appointment time has past before queuing for a room. This ensures that patients are not penalized with long waits because a patient scheduled later arrived early. In contrast, nurses aim to occupy all examination rooms to minimize the possibility of physician downtime. If a room becomes available and the next patient has not arrived, then a subsequent patient can be placed into the room. Once in the room and regardless of the placement process, the patient then queues for the physician on a “first-in, first-out” basis. This logic is incorporated in our model.

We fitted service time distributions for process steps within the model. Key process steps for the patient include: patient preparation time, physician interaction time (including that with residents and medical students), physician turnaround time, and time spent by the patient in the room after the consult. The distributions are specific to the program and appointment type level. Similarly, we fitted turnaround time for physicians from the collected data. We used theoretical distributions when possible. In a few selected cases, where the sample size of the data was small or there were multimodal distributions, we used continuous empirical distributions. We performed sensitivity analysis over the empirical distributions to ensure the approximations did not significantly skew overall results. We found only limited impact in the results when the empirical distributions were modified within reasonable ranges.

Residents and medical students are common within the ACU and are included in the model. Their involvement in the clinic ranges from shadowing oncologists, to assisting oncologists with patient information retrieval, to actual consultation and diagnosis. Residents and students are not present during every oncologist’s clinic. However, when they are present, they work with oncologists on several cases spread over the duration of the clinic. The selection criteria of these cases vary between oncologists. For model simplicity, the assignment of patients to residents and students is performed randomly based on the observed probability of cases with residents and students involvement. During data collection it was difficult to distinguish between residents and students. Therefore, we grouped residents and students and modeled both as one resource type. Data analysis showed multiple patient-physician interaction patterns for cases in which residents or students were involved. We modeled the most frequent patterns to capture the general characteristics of oncologist and resident/student interaction.

General assumptions of the model are that the clinics operate independently of others since there is no patient sharing between clinics. All cancellations and emergency (unscheduled) appointments are factored into the schedule by utilizing historical schedules that already incorporate those events. Patients queue for processes using “first-in first-out,” except for the allocation of rooms. Service times are independent and identically distributed (i.i.d.), indicating that service times do not change if the clinic becomes increasingly congested. In reality, process times are affected by congestion and delays, but the overall logic deemed to be acceptable by both clinicians and our team.

To evaluate the performance of each scenario, we used the following key metrics: patient wait time (average, percentiles), clinic end time, and physician idle time. In addition, resource utilization metrics including waiting room occupancy and examination room utilization were collected and analyzed.

We note that, in agreement with the literature, we report patient wait times computed from the latest of the appointment time and the patient arrival. This prevents over- and under-estimating wait times when patients are early and late with respect to the appointment time, respectively.

Exploiting the graphical capabilities of the modelling software, we embedded the floor plan of the ACU in the simulation model and animated the entire appointment process as it occurred (Figure 5). This helped to validate the model with physicians and staff as they were able to see what was happening real time as the simulation took place.

![Figure 5: Screenshot of the simulation model](image-url)
3.5 Model Verification and Validation

We verified the operation of the model by tracing entities through the processes to ensure the model logic is correct. We tested extreme conditions to confirm the model performed as intended. We also consulted managers and physicians on summarized volumes and process metrics, to ratify high-level results. The animation of the ACU appointment process contributed significantly to ease of model verification and communication with key stakeholders.

For model validation we compared simulated output with collected data. We considered metrics that were independent of input parameters specified in the model, including mean patient wait time until first physician, mean total patient time in the system, mean effective room utilization (ERU), and mean total physician interaction time.

We constructed ninety-five percent confidence intervals for both the simulated and collected metrics. Table 2 shows a comparison between simulated and actual values, aggregated for the two major oncology programs.

We constructed ninety-five percent confidence intervals for both the simulated and collected metrics. Figure 6 shows a comparison between simulated and actual data over several key metrics for model validation.

Table 2: Comparison of simulated and actual data over several key metrics for model validation

<table>
<thead>
<tr>
<th>Model Validation</th>
<th>Simulated vs. Actual Metrics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Program</td>
<td>Metric</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Radiation</td>
<td>Patient Wait Time (min)</td>
</tr>
<tr>
<td>Radiation</td>
<td>Total Time in System (min)</td>
</tr>
<tr>
<td>Radiation</td>
<td>Effective Room Utilization (%)</td>
</tr>
<tr>
<td>Medical Oncology</td>
<td>Patient Wait Time (min)</td>
</tr>
<tr>
<td>Medical Oncology</td>
<td>Physician Interaction Time (min)</td>
</tr>
<tr>
<td>Medical Oncology</td>
<td>Total Time in System (min)</td>
</tr>
<tr>
<td>Medical Oncology</td>
<td>Effective Room Utilization (%)</td>
</tr>
</tbody>
</table>

Table 2: Comparison of simulated and actual data over several key metrics for model validation

With the exception of patient wait times for medical oncology, all simulated metrics fall within the 95% confidence interval of the actual data, indicating the simulation model provides an accurate representation of the ACU appointment process. The model slightly over-predicts wait times for medical oncology patients. Further analysis into the distribution of simulated and actual wait times indicates that a slightly longer tail exists in the simulated data. This tail may be attributed to several factors. The distributions within the model are assumed to be i.i.d. In actuality, when a clinic is running behind, physicians would adjust their consultation time to prevent excessive overtime. The i.i.d. assumption may lead to a longer tail, not present in reality.

Other metrics of interest for validation purposes, such as physician idle time and clinic end time, were not actively captured during the data collection study, mainly due to observational problems (physicians located behind closed doors during most of the clinics hours). Therefore, we could not perform a direct validation of these metrics. We believe that since these metrics are inter-related to those we were able to compare, a successful validation of the listed metrics indicate that both physician idle time and clinic end time are reasonably representative as well.

4. Scenario Analysis

Guided by the findings from the data analysis and the potential opportunities to use resources more efficiently, we developed a series of scenarios for evaluation through computer simulation to test the impact of changes in the processes on resource utilization and other performance indicators.

Overall, we ran and analyzed more than 100 scenarios. Each of them considers actual ACU appointments for a one-month period, replicated 100-times to capture the variability of the process. Appointments from January 2008, the month with the highest patient volume over the past year, were selected to test the model.

Each scenario is represented by a unique combination of levels for all the factors tested. We classified the factors considered for the analysis in three groups: Operational, Appointment Scheduling, and Resource Allocation. Figure 6 shows all the factors and their corresponding levels as tested in the simulation model.

4.1 Operational

These are factors related to the operations or processes of the system:

- Clinic Start: impact of clinics’ start time on the performance of the system. We considered two levels: i) distribution with mean 7 minutes late...
(current state), and ii) distribution with mean zero (start on time).

- Resident/student: impact of resident/student involvement in the appointments. We studied two levels: i) residents/students participate as per current rates (current state), and ii) no resident/student involvement.

4.2 Appointment Scheduling
In this category we group all factors that are related to different scheduling practices:

- Appointment Order: impact of scheduling appointments based on their duration and variability. We tested three levels representing alternatives of the order in which New-patient (N), Follow-up (F) and inter-program Consult (C) appointments are scheduled: i) F-C-N, ii) N-C-F, and iii) F-N-C.

- Appointment Adjustment: impact of increasing the time allocated for each appointment. We studied two categories:
  - Fixed Duration Increase: impact of increasing the time allocated for each appointment. We considered three levels: i) current duration, ii) 15% longer, and iii) 30% longer.
  - Appt. Specific Duration Increase: impact of adjusting appointment times based on actual (sampled) visit duration, by appointment type and program. We evaluated two levels: i) current state, and ii) reschedule based on estimated physician turnaround duration.

- Add-ons to the Schedule: impact of unscheduled cases (add-ons) in the schedule. We considered two levels: i) add-ons scheduled any time in the clinic (current state), and ii) add-ons scheduled at the end of the clinic.

4.3 Resource Allocation
These are factors related to changes in the way resources—examination rooms in particular—are allocated and used.

- Pod Configuration: impact of room allocation and room layout. Two levels were tested: i) separate pods with dedicated rooms per clinic (current state), and ii) pool pods with shared, flexible room allocation.

5. Results
Results from these scenarios show that there are opportunities to significantly improve processes in the ACU, increasing resource utilization and decreasing patient wait times.

Figure 7 shows the change in wait time (horizontal axis) and clinic duration (vertical axis) for the scenarios tested using the simulation model. The current state is located in the intersection of both axes (the origin).

Because the objective is to reduce the average wait time for patients, while reducing or not significantly increasing the clinic duration, the “best” points are in the lower left quadrant of figure 6. The set of non-inferior points (those that achieve the best performance in one metric for a given value of another metric) form the “efficient frontier.”

The scenarios with the best performance show a potential reduction of up to 70% in average wait time (from the current 21 minutes to 6.4 minutes), while only increasing the clinic duration by 10%. Figure 8 depicts these results and their corresponding configuration factors. For instance, the best case in terms of wait time (rightmost) is achieved by: having clinics starting on time,
increasing appointment durations by 30%, and scheduling add-ons at the end of the clinic.

Table 3 shows the patient wait time and clinic end time for the selected scenarios as the different factors are varied from current conditions. In addition to averages, we also evaluated the 90th percentile of wait times. For this measure, a potential reduction of up to 30 minutes in wait times is observed under the scenario with the largest improvement.

### 6. Discussion

#### 6.1 Findings from the Simulation Model:

In terms of the individual configuration factors tested using our simulation model, we found the following:

- **Clinic Start:** Results show that delays in starting the clinic have a significant impact on patient wait time as almost all appointments are affected by the late start. For the levels we considered in the scenarios, wait time could be reduced by 15% (3.1 minutes on average) if there was no delay.

- **Resident/student:** Results from the simulation model considering a scenario where no residents or students are involved in the ACU appointments provide a comparison point to estimate the burden or cost that academic and teaching duties generate on the system.

When compared to the current situation, our analyses show a minimum change (10% reduction for medical oncology, no change for radiation oncology) in the number of examination rooms required if no resident/student participation occurs (and no other changes are considered). However, results show that average wait time actually decreases by up to 24% (5.3 minutes) for clinics in the medical oncology program in the case of no resident/student involvement (no change for clinics in radiation oncology).

- **Appointment Order:** After analyzing the different scenarios for this factor, no significant improvement has been identified by any particular configuration. This is because of the structure of ACU clinics, which comprise mostly Follow-Up appointment (85% of the total, followed by 10% New-patients) and do not mix appointments frequently (only 30% of the schedules have both Follow-up and New-patient appointments in the same clinic), making the appointment order less relevant.

In general, scheduling Follow-Ups first, with New-patients or Consults afterwards has little impact on wait times, but results in a slight decrease in total clinic duration.

- **Appointment Adjustment:** Results show that only the fixed duration increase in the appointment time has a significant impact. This causes appointments to be scheduled further apart, reducing the probability of overlap and subsequent wait time. This reduces patient wait times by up to 43% (9 minute reduction), while increasing clinic duration about 10%.

- **Add-ons to the Schedule:** Results for these three groups are similar in terms of their effects on patient wait time and clinic duration. All of them cause appointments to be scheduled further apart, reducing the probability of overlap and subsequent wait time. This reduces patient wait times by 18% (3.8 minute reduction), while increasing clinic duration only marginally (less than 1%).

- **Pod Configuration:** Using a more flexible approach to allocate examination rooms to physicians, such as a pool of shared rooms instead of the current designated rooms per clinic, significantly reduces the number of rooms needed to run the exact same number of clinics and patients.

Results from the simulation model show that if a pool of resources by program is used, up to 10 examination rooms (6 in the medical oncology program and 4 in the radiation oncology program) can be saved without significantly affecting patient wait time or other performance measure. This means that the equivalent of roughly 2 pods can be used for other duties, such as supplementary physician space, the operation of more clinics, or the expansion of adjacent areas.

Figure 9 shows the resulting average wait time for clinics in the medical and radiation oncology programs, for different levels of examination rooms available by program. The current number of available examination rooms is 22 for medical oncology and 16 for radiation oncology; this sets
the reference point for comparison. As the number of rooms in the pool is decreased in the simulation model, we observe no significant change in average wait time until 6 or more examination rooms are eliminated for medical oncology clinics, and 4 or more for radiation oncology clinics. The same effect is observed for other measures, such as clinic duration and physician idle time, and other metrics of the same measures (e.g., 90th percentile). At those points, the number of examination rooms available per program becomes the limiting resource in the system, causing clinic duration, physician idle time, and other measures to deteriorate compared to the current performance level.

6.2 Lean Perspective:
The findings from this project are in alignment with those the lean approach would identify. From a waste elimination viewpoint, delays in starting clinics, excessive patient wait during the consult, and unnecessary examination room utilization are the main issues to be addressed. In each of these situations there is no value added to the patient (or anyone else). There is also unnecessary ‘work in progress,’ represented by patients that have initiated their appointment but are waiting for additional steps in the process for their appointment to be finalized.

The challenge is then to find a mechanism to eliminate all the waste in such a complex system and examine different scenarios. Our simulation model allowed us to take the next step and test a large number of individual and simultaneous changes in the processes and evaluate the resulting performance.

6.3 Patient Wait Time Survey:
To complement this study and capture the patient perspective on different aspects of ACU operations, we designed a patient wait time satisfaction survey, and carried out a pilot study.

Although results obtained from the pilot survey are only preliminary, important information was identified in terms of patients’ preferences. Initial findings indicate that, in general, patients are satisfied with their wait experience in the ACU, and prefer to wait in the waiting area rather than in the examination rooms.

With the full patient survey we expect to collect useful information with regards to what wait times patients find acceptable and other operational aspects. These are additional factors that can be incorporated in the design of both the facility and the processes. Using our simulation model we will be able to determine the optimal processes to achieve the desired performance.

We plan to repeat the survey after implementing changes and compare patients’ perceptions. Results from the survey will be reported in a separate publication.

6.4 Data availability:
One of the challenges we faced in this project was the lack of data in the form required to develop models such as the one we implemented. In our opinion, and based on our experience in similar projects with other health care organizations, this is a recurring problem for this sector.

In the past, data were collected primarily for costing purposes. More recently, the focus has been on the integration of clinical, imaging, order entry, and other information systems to implement electronic patient records.

Process-related information has received little attention; it is hardly measured, let alone stored in a data base/warehouse. The lack of data prevents the execution of in–depth studies based on modern management methodologies. Furthermore, having no baseline and post-implementation data inhibits the execution of a proper evaluation of the implementation of changes to the processes. This is an issue that needs to be addressed at the industry level.

6.5 Conclusion:
The simulation model developed in this study provides valuable insight into the factors in the appointment process that can help reduce patient wait time and improve resource utilization.

Our main conclusions are the following:
1. To achieve significant improvements in terms of wait time reduction, a series of strategies need to be implemented simultaneously. There is no single action that results in a major
reduction, but the combination of several strategies can cause a significant change (up to 70% reduction in our case).

2. The addition of flexibility to how rooms are currently allocated and utilize show promising results in terms of examination room capacity (up to 25% reduction in our case). Replacing the current ‘dedicated’ model for the allocation of rooms to clinics by a ‘dynamic’ paradigm that allows sharing rooms among different clinics can significantly reduce the number of rooms required to treat the same number of patients while preserving the performance standards to the patients.

Based on the findings from this study we recommend the following high-level actions to improve the performance of this ACU:

a) Redistribute clinic workload more evenly across the week and time of the day, to reduce peaks in patient volume and resource utilization

b) Allocate examination rooms more flexibly and dynamically among individual clinics within the medical, radiation and surgical oncology programs, to better utilize available capacity

c) Promote clinic punctuality to avoid delays in the start of the clinic and efficient running of the clinic to reduce overtime

d) Re-evaluate scheduling practices (for each physician) to ensure they accurately represent the type and duration of appointments being booked.

In addition, we recommend to collect process-related data systematically, both to allow the development of future models, and for monitoring and evaluation purposes.

6.6 Implementation:
The recommendations proposed in this study are currently being evaluated for implementation by senior management. Some areas that will need to be addressed to carry out the recommended changes are:

- The redistribution of clinic workload requires significant adjustments in the physicians' schedules, at least for some of them. Regular meetings such as patient review conferences also need to be rescheduled accordingly.
- Implementing a flexible, dynamic room allocation within the existing physical space entails changes mainly in the roles and responsibilities of nursing staff. It also requires the support of an IT solution to coordinate room allocation, indicating where patients are located, where a physician should go next, and the occupancy status of every examination room.
- To put into action punctual start of the clinics requires multiple conditions. First, all patients, physicians and nurses need to be on time. Second, the required information, including patient records and test results, has to be available at the beginning of the clinic.
- The re-evaluation of scheduling practices involves the analysis of individual physician practice. Accurate appointment durations for every patient category need to be estimated on a physician-specific basis. A general policy to deal with appointment add-ons need to be implemented.

Adequate data should be collected before and after any implementation to evaluate its impact. We are currently investigating various methods to capture data in a more efficient and sustainable manner.

In addition to gaining a better understanding of the processes in the ACU, this study contributed to disseminate among physicians and management the usefulness of Operations Research methodologies in aiding knowledge-based decision making.
Acknowledgements
This work was funded in part by a research grant from the Canadian Institutes of Health Research (CIHR) in support of The CIHR Team in Operations Research for Improved Cancer Care (www.ORinCancerCare.org/cihrteam).

We thank all the administrators, physicians, nurses and clerks at BCCA’s Vancouver Centre for their contribution in this project. In particular, we are grateful of the valuable insight and direction provided by Dr. Kim Chi, Lorna Roe, Frankie Goodwin, Michelle Dumas, Pam Stewart, Lindy McKinnon, Pam Taheem, Krystyna Olkiewicz and Suzanne Ratchford.

References


