Process Redesign & Optimization-Based Tools to Improve Outpatient Appointment Scheduling

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The CIHR Team

- Oncologists
- Administrators
- Statisticians
- Faculty
- Researchers
- PhD Students
- Post-doc fellows
- Operations Research Professionals

BCCA

UBC
The Presentation in One Slide

- Background: scheduling for outpatient clinic
- Problem: late appointment confirmation and long waitlist
- Causes: outdated, over-constrained processes
- Solution: addition of flexibility through process redesign and optimization-based scheduling tool
- Results: 58% reduction in late appointment confirmation; 84% decrease in waitlist; patient/staff satisfaction improvement
• Province-wide, population-based cancer control program for residents of British Columbia & Yukon

• Full spectrum of cancer care, from prevention and screening, to diagnosis, treatment, and through to rehabilitation
Cancer Treatment Options

- Surgery
- Radiotherapy
- Chemotherapy
  - Drug treatment:
    - orally
    - intravenously
  - Mostly outpatient
Chemotherapy Unit in Vancouver Centre

- 14,000+ appts/year:
  - 60-65 patients/day
  - 200+ protocols
  - ½ to 10+ hrs treatment
- 10 nurses,
  9 rooms, 33 chairs
- Open 09:00 to 19:00
Chemotherapy Scheduling Challenges

- New patients:
  - Provincial, National and Clinical Guidelines for Lead Times

- Continuing patients
  - Possible adverse reactions during treatment
  - Uncertain appointment durations
  - Resource requirements
  - Side effects between treatments
  - Cancellations or delays
  - Multiple appointments on a precise schedule
    - Booked at same time or sequentially

- Varying resource requirements
  - Nurses, chairs, pharmacy

- System operating at capacity
Processes of Interest

- **Stage 1: appointment booking**
  - Oncologist requests treatment for patient
  - Clerk books required appointment(s) in available slot(s)
    (4 month to 1 week in advance)

- **Stage 2: appointment scheduling**
  - Booked appointments are assigned to nurses
    (1 day before treatment date)
Appointment Process Redesign:

Symptoms
Symptoms

- Operations:
  - Patients: late notification
  - Nurses: uneven workload and complexity distribution
  - Clerks: extensive rework; difficult scheduling
  - Pharmacy: drug preparation capacity exceeded
  - Oncologists: frustrated patients; delays to start treatment

- Complaints, stress, low morale, dissatisfaction…
  and potentially adverse impact on health outcomes
Symptoms by the Numbers

- In the data:
  - Late appointment confirmation:
    - 42% > 7 days (IQR: 11)
    - 22% > 3 days (IQR: 21)
  - Waitlist:
    - 24 patients 1 week in advance (IQR: 15)
    - 6 patients 1 day in advance (IQR: 8)
  - Appointment availability:
    - 11 days to first available appointment (IQR: 9)
  - Pharmacy capacity:
    - 9 treatment starts exceeding 15-minute capacity (IQR: 4)
    - 65 preparation starts exceeding 60-minute capacity (IQR: 51)

Figures based on extensive data analysis of appointment data from CAIS, BCCA information system.
Appointment Waitlist

Chemotherapy Appointment Waitlist
(1 week before)

<table>
<thead>
<tr>
<th>Appointment Date</th>
<th>Waitlist Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan-09</td>
<td>10</td>
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<tr>
<td>Feb-09</td>
<td>20</td>
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<tr>
<td>Mar-09</td>
<td>30</td>
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<tr>
<td>Apr-09</td>
<td>40</td>
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<td>May-09</td>
<td>50</td>
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<tr>
<td>Jun-09</td>
<td>60</td>
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<td>Jul-09</td>
<td>70</td>
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<tr>
<td>Aug-09</td>
<td>80</td>
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<tr>
<td>Sep-09</td>
<td>90</td>
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<tr>
<td>Oct-09</td>
<td>100</td>
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<tr>
<td>Nov-09</td>
<td>110</td>
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<tr>
<td>Dec-09</td>
<td>120</td>
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<tr>
<td>Jan-10</td>
<td>130</td>
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<tr>
<td>Feb-10</td>
<td>140</td>
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<td>Mar-10</td>
<td>150</td>
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<td>Apr-10</td>
<td>160</td>
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<td>May-10</td>
<td>170</td>
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<td>Jun-10</td>
<td>180</td>
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<td>Jul-10</td>
<td>190</td>
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<td>Aug-10</td>
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<td>210</td>
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<td>Oct-10</td>
<td>220</td>
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<td>Nov-10</td>
<td>230</td>
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<tr>
<td>Dec-10</td>
<td>240</td>
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Impact on the Patient

- Cancer and chemotherapy can be physically and emotionally challenging; no need for added stress!
- Appointment uncertainty problematic because:
  - Need for advanced notice to coordinate transportation
  - Sufficient confirmation to take pre-treatment drugs
  - Travel complications and additional financial burdens for those traveling from outside Metro Vancouver
Appointment Process Redesign:
The Causes
Old Process:
Booking a Chemotherapy Appointment

- Oncologist Orders Chemo Treatment List
- Chemo Waitlist Confirmation to Patient

Scheduling Process:
- Late confirmation

Ambulatory Clinic Chemo Unit
Old Process:
Protected Capacity and Waitlists

- Patient waitlisted when there is no capacity left for that treatment type.
- There is capacity available but it is restricted to other treatment types.
- There may be flexibility in appointment day but old process did not use it.
Old Process:
Finalizing Treatment List in Chemo Unit

One or two days before the treatment date:

- Manage capacity:
  - Release pre-specified capacity
  - Add nursing time
  - Cancellations

- Manage demand:
  - Triage patients
  - Re-schedule patients to different days based on clinical tolerance
    - These were not carefully defined or used
## Old Process

**Treatment Schedule**

<table>
<thead>
<tr>
<th>Day 1</th>
<th>Day 2</th>
<th>Day 3</th>
<th>Day 4</th>
<th>Day 5</th>
<th>Day 6</th>
<th>Day 7</th>
</tr>
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Identified Problems

- Root causes:
  - Over-constrained capacity:
    - Several spot types with reserved capacity
    - Reservation levels were ad hoc and static
  - Inflexibility in existing booking and scheduling processes:
    - Delayed use of tolerance and release of protected capacity
    - Difficult to assess impact of last-minute changes to schedule on nurse and pharmacy workloads

- Leads to:
  - Unnecessary capacity conflicts
  - Inefficient use of existing capacity!

- Need to effectively use flexibility in the process
Appointment Process Redesign:
Our solution
Process Redesign:
Evaluation Through Simulation

INPUT
12,300 appl 2008/2009

Computer Simulation Model

OUTPUT
Waitlist Confirmation time Utilization

Process Changes
Process Redesign:
Evaluation Through Simulation

<table>
<thead>
<tr>
<th>Appointment Date</th>
<th>Appointments</th>
<th>Daily Waitlist Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Old Process</td>
<td>Scenario 1</td>
<td>Scenario 2</td>
</tr>
<tr>
<td>with tolerance</td>
<td>without tolerance</td>
<td>with tolerance</td>
</tr>
</tbody>
</table>
Process Redesign: Evaluation Through Simulation

[Graph showing appointment dates and daily waitlist size with comparison between old process and scenarios with and without tolerance]

- Appointments
- Appointment Date
Redesigned Process: Booking a Chemotherapy Appointment

Oncologist

Orders Chemotherapy

List

Chemo Waitlist

Confirmation to Patient

Chemo Treatment List

Scheduling Process

Confirmation to Patient
Our Solution

- Simulation model used to determine process changes with highest impact

- Key redesign elements:
  - Eliminate most protected capacity
  - Use treatment tolerance in booking stage
  - Create schedule one week before treatment (assign start times & nurse)
**New Challenge**

- Redesigned process makes second stage scheduling very difficult:
  - No pre-assigned times
  - Apointments need to be assigned start time and nurse
  - Constrained capacity and clinical considerations
  - Conflicting appointments and preferred start times

- Potential opportunity to improve scheduling
  - Improve workload and complexity balance across nurses
  - Better adherence to pharmacy capacity constraints

Solution: advanced analytics (optimization-based scheduling model)
Appointment Process Redesign: The Implementation
Implementation Challenges

- 6 units involved:
  - Chemotherapy unit
  - Ambulatory clinic
  - Oncologists
  - Pharmacy
  - Clinical trials
  - IT/IS
- Bureaucratic organization
- IT system redesign
- Staff training
- Use of advanced analytics by clerical staff
Scheduling Problem

Nursing Time

Chair Time

Scheduling Problem
An Ideal Schedule

- All patients are scheduled:
  - During regular time (not during shift breaks)
  - Under supervised care (before 4PM for hot drugs)

- Nursing workload:
  - Even distribution (within and across nurses)
  - ≤ 57 pats/nurse (4 AM, 4 PM)
  - Similar nursing time utilization
  - ≤ 1 new pat/nurse
  - ≤ 2 push-drug pat/nurse (1 AM, 1 PM)
  - ≤ 3 GI pat/nurse (2 AM, 2 PM)
An Ideal Schedule

- Pharmacy workload:
  - ≤1 clinical trial per 30-min
  - ≤4 pats per 15-min; ≤6 pats per 60-min
  - ≤6 preps per 15-min; ≤14 preps per 60-min
  - ≤130 preps per day

- Other scheduling constraints:
  - Doctor/labs appointments
  - Patient time constraints/preferences
Scheduling Model:

Decision Variables:

\[ x_{ijk}^p = 1 \text{ if patient } p \text{ is scheduled at treatment slot } i \text{ on chair } j \text{ of nurse } k, \quad 0 \text{ otherwise} \]

\[ x_{ijk}^p \in \{0,1\} \]
Scheduling Model:
Deviations & Multi-criteria Optimization

- General form: \[ \sum (x - \alpha) \leq C \]
- Soft approach: \[ \sum (x - \alpha) - (\delta - \hat{\delta}) \leq C \]
- Objective function: \[ \text{Min } \Lambda + \sum w_j (\delta_j^w + \delta_j^d) \]
Problem Structure

- Generalized assignment problem:
  - Patient i assigned at most to one nurse j
  - Nursing time capacity
  - Binary variables

\[
\text{Min } \sum_{i=1}^{n} \sum_{j=1}^{m} c_{ij} x_{ij}
\]

\[
\sum_{i=1}^{n} x_{ij} \leq 1
\]

\[
\sum_{j=1}^{m} x_{ij} \leq \text{NT}_i, \quad \forall i
\]

\[
x_{ij} \in \{0,1\}
\]

- Side constraints specific to chemo process:
  - Second resource: chair (consecutive job)
  - Pharmacy capacity (previous job)
  - Multiple capacity levels (patient types per nurse)
  - Time windows (job-specific)
The Scheduling Model in Numbers

Typical scenario:
- ~60 patients to be scheduled
- 8-9 nurses (8-hr shift; 6-hr of effective treatment time)
- 4 chairs per nurse
- 10-hr workday (9:00 to 19:00) divided in 15’ slots

Resolution:
- Decision variables: 33,500+ (most binary)
- Constraints: 2,750+
- Solution time: <5 min for 2-5% gap
- Modeling platform: GAMS/CPLEX
- Tool platform: web + MS Access
Scheduling Tool

- Interface for managers to review & modify schedule
- Initial schedule generated by the optimization model
- Patients can be re-scheduled across nurses
  - Constraints are checked in "real time" and warnings/error messages reported to user
  - Workload stats are updated after every change
- Web-based interface and platform
Appointment Process Redesign: The results
Evaluation Framework

- Patients
  - Utilization
  - Capacity availability
  - Pharmacy workload
  - Waitlist size
  - Confirmation time
  - Nursing workload
  - Clerical rework

- Staff
  - Satisfaction
  - Reasonable conf. time, # changes

- Administration
  - Workload
  - New process

- Transferability to other centres and clinics
Quantitative: Appointment Waitlist

<table>
<thead>
<tr>
<th>Appointment Date</th>
<th>Pre-Implementation</th>
<th>Post-Implementation</th>
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<tbody>
<tr>
<td>Jan-09</td>
<td>46</td>
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<td>Dec-10</td>
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</tbody>
</table>
## Quantitative Summary

<table>
<thead>
<tr>
<th>Metric</th>
<th>Pre-Implementation</th>
<th>Post-Implementation</th>
<th>Decrease</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Patients</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Waitlist size</td>
<td>Before appointment</td>
<td>After appointment</td>
<td>% Decrease</td>
</tr>
<tr>
<td>One day before appointment</td>
<td>6</td>
<td>3</td>
<td>50%</td>
</tr>
<tr>
<td>One week before appointment</td>
<td>24</td>
<td>4</td>
<td>83%</td>
</tr>
<tr>
<td><strong>Confirmation time</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Appointments confirmed &lt; 7 days (% appts. per day)</td>
<td>42%</td>
<td>18%</td>
<td>58%</td>
</tr>
<tr>
<td>Appointments confirmed &lt; 3 days (% appts. per day)</td>
<td>22%</td>
<td>11%</td>
<td>50%</td>
</tr>
<tr>
<td><strong>BCCA</strong></td>
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<tr>
<td>Pharmacy capacity</td>
<td>Daily treatment starts exceeding 15' capacity</td>
<td>9</td>
<td>5</td>
</tr>
<tr>
<td>Daily preparations exceeding hourly capacity</td>
<td>65</td>
<td>45</td>
<td>31%</td>
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</tbody>
</table>

Evaluation timeframe:
1. Pre-Implementation: June 29th to October 23th, 2009
2. Post-Implementation: June 28th to October 22th, 2010

Figures shown: median
Process Redesign:
Evaluation Through Simulation

Daily Waitlist Size

Appointments

Appointment Date
Process Redesign: Evaluation Through Simulation

Appointments

Appointment Date

Daily Waitlist Size

Old Process
Scenario_1
Scenario_2
Current
• Patient appointment satisfaction survey
  - Changes to appointments
  - Notification time

![Graph showing satisfaction versus notification time before and after implementation.](image)
Qualitative:
Patient Survey

- Earlier appointment date notification, higher patient satisfaction (p<0.001)
  - confirmation time ≤ 5 days: 68% satisfied
  - confirmation time > 5 days: 99% satisfied

Patient appointment satisfaction survey sample size:
• Pre-implementation: 362 total collected; 308 included in analysis
• Post-implementation: 352 total collected; 317 included in analysis
Qualitative:
Patient Survey Comparison

- Changes in the process confirmed by patients (p<0.001)

Date and Time Notification within 5 Days
Pre and Post Implementation

*Graph showing pre- and post-implementation changes in date and time notification.*
Qualitative Patient Survey

- Significant improvements in satisfaction due to new booking process

![Graph showing satisfaction with date and time notification pre- and post-implementation. Pre-implementation satisfaction is lower than post-implementation for both date and time notifications.]
Qualitative:
Staff Survey/Interviews

- Booking clerks survey:
  - Over 80% prefer new booking process to previous one
  - Over 40% noted a reduction in stress level and time required to book a patient while none reported increases

- Interviews:
  - Overall positive feedback; fine-tuning required
  - Better workload distribution
  - Implementation and support was good
  - Realized potential of advanced analytics
Summary and Discussion
Summary

- The changes:
  - Redesign of processes to better use flexibility
  - Development of optimization-based scheduling tool

- Successful implementation under multiple criteria
  - Increased notification times, reduced waitlist
  - Improved workload distribution and capacity adherence

- Other benefits:
  - Standardization and formalization of processes
  - Use of advanced analytics for process improvement
  - Additional data for other analyses
Discussion: Implementation Challenges

- Process redesign:
  - Develop optimization tool that can be easily used by clerk
  - Implement IT changes in system up for replacement

- Change management:
  - Convince management of potential improvements
    (and deliver on promised results!)
  - Standardize and officialize scheduling practices
  - Train users in new process and monitor adherence

- Scheduling model:
  - Balance multiple goals to represent true objective
  - Solve efficiently to provide solution quickly
### Research Opportunities/Challenges

- Dynamic reservation policies by appointment class
- Use of appointment flexibility at booking
- Dynamic addition of nursing capacity
- Cancellations prediction and management
- Overbooking
- Variability in appointment durations
- Reverse optimization – choosing criteria weights