Hôpital général juif
Jewish General Hospital

On Coming Closer To Achieving Target Cancer Surgery Wait Times

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HÔPITAL D'ENSEIGNEMENT DE L'UNIVERSITÉ MCGILL | A MCGILL UNIVERSITY TEACHING HOSPITAL

A Conversation With The Jewish General's Hospital CEO

- **Several months ago Nadia Lahrichi and I had a conversation with the hospital's new CEO**

- **It went something like this:**

  - **“I have an interesting problem for you guys.**

  - **Based on the available operating room time, number of surgeons and volume of cancer cases, I need to prove that it is impossible for us to do all cancer surgery cases within 28 days!**

  - **We are currently running at an average of 44% (see attached spreadsheet)”**

Preliminary Constraints

- For our analysis we were not allowed to change the system
  - Surgeons needed fixed time slots they could count on
  - They could not be asked to change their schedule regularly

Analysis

- **To determine whether it would be possible to ensure that cancer surgeries could (nearly) all be performed within the 28 day period mandated by the Quebec government, we:**
  - **Determined, for each surgeon, the amount of OR time needed to perform cancer surgeries, by the week in which those procedures were requested**

    Consistent with the next step this did not include turnover time.
  - **Determined, for each surgeon, the amount of OR time used for all of their surgeries, by the week in which those surgeries were performed**

    Consistent with the previous step, this did not include turnover time.

Analysis

- **Observed that the total OR time available per year per surgeon was MORE than the time needed by that surgeon for cancer procedures for 7 of the 8 top cancer surgeons at the hospital**

- **Insufficient time is not the cause of long delays for cancer surgeries in almost all cases.**

Analysis

- **Compared the OR time demanded by new requests per week, versus the availability or OR time per week.**

- **We observed that in some weeks there was much more demand than supply, and that in other weeks there was much more supply than demand.**

- ***Weeks with demand from new requests greater than available time increase waiting.***

Demand And Availability - Surgeon L

Year	Week	Cancer Request Minutes	All OR Minutes	Cancer Request Minutes	OR Minutes
2012	36			985	
				332	239
					691
				203	636
				1712	
2012	41			769	499
				329	486
				627	
				737	902
					394
					740
				672	1563
				373	1069
				214	1238
2012	51			833	367
2013	1				362
				363	
				813	
					494
				722	403
				755	
				243	330
				516	
				300	680
				713	
2013	11			668	374
				256	243
				298	640
					648
				499	328
				225	427
					429
				1061	456
2013	21				257
				0	424
				715	604
				1672	467
				1280	707
				626	786
				298	
				83	
				834	458
2013	31			936	1545
				535	713
				726	
					283
				467	
TOTAL				23390	20882

Demand And Availability – Surgeon B

Year	Week	Cancer Request Minutes	All OR Minutes	Cancer Request Minutes	OR Minutes
2012	50	[illegible]	[illegible]	190	577
			[illegible]		520
		[illegible]	[illegible]	602	631
		[illegible]	[illegible]	476	443
		[illegible]	[illegible]	1119	571
2012	41	[illegible]		467	
		[illegible]	[illegible]	215	885
		[illegible]	[illegible]	60	1155
		[illegible]	[illegible]	434	788
		[illegible]	[illegible]	540	815
		[illegible]	[illegible]	460	570
			[illegible]		750
		[illegible]	[illegible]	1199	488
		[illegible]	[illegible]	440	234
		[illegible]	[illegible]	1096	875
2012	51		[illegible]		452
2013	1				
		[illegible]	[illegible]	207	454
		[illegible]	[illegible]	240	535
			[illegible]		1085
		[illegible]	[illegible]	1105	520
		[illegible]	[illegible]	596	722
		[illegible]	[illegible]	400	503
		[illegible]	[illegible]	501	234
		[illegible]		74	
		[illegible]		631	
2013	11	[illegible]	[illegible]	1054	400
		[illegible]	[illegible]	267	567
		[illegible]	[illegible]	405	797
		[illegible]	[illegible]	1100	561
			[illegible]		999
		[illegible]	[illegible]	174	1094
			[illegible]		400
		[illegible]	[illegible]	426	409
			[illegible]		451
		[illegible]	[illegible]	778	410
2013	21	[illegible]		601	
		[illegible]	[illegible]	232	487
		[illegible]		40	
		[illegible]		1104	
		[illegible]	[illegible]	380	425
		[illegible]	[illegible]	1428	408
			[illegible]	0	403
		[illegible]		300	
2013	31				
		[illegible]	[illegible]	79	1057
		[illegible]	[illegible]	143	1087
		[illegible]	[illegible]	434	702
		[illegible]	[illegible]	337	637
TOTAL				**21178**	**24909**

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Analysis

- **Possible reasons for this variability seem likely to include:**
  - **Variability in the number of new cases presented to each surgeon each week.**
  - **Variability in the amount of time each case requires.**
  - **Variability in the amount of available OR time each week (due to vacations, holidays, . . .)**

Analysis

- **For each surgeon, (hypothetically) applied the available OR time each week to the backlogged demand for cancer surgeries and found that because of the variability discussed above that:**
  - **In some weeks there was practically no backlog of cancer surgeries.**
  - **In other weeks, there were much more than 4 weeks of backlogs of cancer surgeries.**

OR Time Applied To Cancer Procedures

Year	Week	Cancer Request Minutes	OR Minutes	7 Week Old Minutes	6 Week Old Minutes	5 Week Old Minutes	4 Week Old Minutes	3 Week Old Minutes	2 Week Old Minutes	1 Week Old Minutes	0 Week Old Minutes
2012	36	190	577	0	0	0	0	0	0	0	190
			520	0	0	0	0	0	0	190	0
		662	631	0	0	0	0	0	190	0	662
		478	443	0	0	0	0	0	0	662	478
		1119	571	0	0	0	0	0	662	478	1119
2012	41	487		0	0	0	0	91	478	1119	487
		215	885	0	0	0	91	478	1119	487	215
		60	1153	0	0	0	0	803	487	215	60
		454	788	0	0	0	0	137	215	60	454
		540	813	0	0	0	0	0	60	454	540
		486	370	0	0	0	0	0	454	540	486
			750	0	0	0	0	84	540	486	0
		1199	488	0	0	0	0	0	486	0	1199
		446	234	0	0	0	0	0	0	1199	446
		1098	875	0	0	0	0	0	1199	446	1098
2012	51		452	0	0	0	0	324	446	1098	0
				0	0	0	0	318	1098	0	0
2013	1			0	0	0	318	1098	0	0	0
		207	454	0	0	318	1098	0	0	0	207
		246	535	0	0	962	0	0	0	207	246
			1085	0	427	0	0	0	207	246	0
		1105	520	0	0	0	0	0	246	0	1105
		598	722	0	0	0	0	0	0	1105	598
		460	363	0	0	0	0	0	1105	598	460
		301	234	0	0	0	0	742	598	460	301
		74		0	0	0	508	598	460	301	74
		831		0	0	508	598	460	301	74	831
2013	11	1034	460	0	508	598	460	301	74	831	1034
		287	567	48	598	460	301	74	831	1034	287

Results

- **The result of this analysis is that using the current approach to allocating time to surgeons:**
  - **It is not possible without giving surgeons more OR time or reducing their case load, for (nearly) all cancer surgeries to be performed within 28 days.**
  - **If surgeon case loads were decreased (to reduce delays) without increasing their OR time, it could result in lower utilization of their OR time, particularly for surgeons who exclusively perform cancer surgeries.**
  - **If surgeon OR time was increased (to reduce delays) without increasing their case loads, it could also lower utilization of their increased OR time, particularly for surgeons who exclusively perform cancer surgeries.**

How About Trying To Apply Yield Management

- It seems pretty obvious that we would like to maximize the benefit that surgeons provide to the system
- As a starting point we could try to maximize the benefit that individual surgeons provide to the system
- The rest of this presentation will describe some preliminary work being done to try to apply approximate dynamic programming to this problem

Model Parameters

- p the period number
- Lp the number of patient visit slots in period p
- l a specific patient visit slot
- d patient diagnosis
- π_d the probability of getting a particular diagnosis in a visit
- v_d the value of surgeon performing procedure for diagnosis d
- τ_d the number of OR intervals it takes to perform procedure
- p_{min} the earliest period in which a procedure should be performed
- p_{max} the latest period in which a procedure should be performed
- O_p the number of contiguous OR intervals the surgeon has in period p
- α a discount factor

Model State Space

- The state space (s) for the problem consists of a tuple containing:
  - For the current period:
    - l
  - For all future periods:
    - L_p
    - O_p
  - For all accepted procedures (in the order to be performed):
    - P_{min}
    - P_{max}
    - τ_d

- Needless to say the state space is extremely large

State Transformations

- **There are three state transformations:**
  - **$A_{eop}(s)$**
    - **At the end of periods (when the next period's schedule is frozen)**
    - **Remove procedures scheduled in next period**
    - **Renumber procedures to start at 1**
  - **A0(s)**
    - **After making a decision not to perform a procedure for a patient**
    - **Increment l**
  - **$A_{\theta}(s, \tau, p_{min}, p_{max})$**
    - **After making a decision to perform a procedure for a patient**
    - **Increment l**
    - **Add new procedure parameters**
    - **Sort using procedure θ**

Model Decision Variables

- $\xi_{s,d,\theta}$
  - The fraction of patients with diagnosis d to be accepted when the system is in state s and ordering procedure θ is used
  - If equal to:
    - 1 then all patients with diagnosis d are accepted
    - 0 then no patients with diagnosis d are accepted
    - In between that fraction of patients with diagnosis d are accepted
  - $\xi_{s,d,\theta} \in [0, 1]$
  - $\Sigma_{\theta} \xi_{s,d,\theta} \leq 1$ for all s, d

Discounted Dynamic Program

- $V(s) = \max_{\xi_{s,d,\theta}} \Sigma_d \pi_d \cdot$
  $[\quad (\Sigma_\theta \xi_{s,d,\theta} \cdot (v_d + V(A_\theta(s, \tau, p_{min}, p_{max}))))$
  $+ \quad (1 - \Sigma_\theta \xi_{s,d,\theta} \cdot V(A_0(s))) \quad]$

  after each patient is seen

- $V(s) = \alpha \cdot V(A_{eop}(s))$

  after the last patient decision has been made for a period

Computational Challenges

- **Determining when accepting a patient will violate constraints**
- **Ordering of procedures**
- **State space**

Identifying Constraint Violations

- **Formulate a 0/1 integer linear program:**
  - **0 coefficients in objective function**
  - **The following constraints:**
    - $x_{i,p}$
      - $\in \{0,1\}$ if $p_{min} \leq p < p_{max}$
      - 0 otherwise
      - i is the procedure number (and not its order)
    - $\sum_p x_{i,p} = 1$ for all i
    - $\sum_i \tau_i \cdot x_{i,p} < O_p$ for all p

Ordering The Procedures

- It's not obvious (to me) the best approach to use to ordering the procedures

- Possibilities include:
  - Earliest latest period first
  - Weighted earliest latest period first (with τ)
  - Minimize remaining procedure time in each period
  - Weighted earliest latest period first and minimize remaining procedure time in each period

- Because it is not obvious θ was included in DP

- Developed a heuristic for the last possibility

Reducing The State Space

- Trying to identify approximately equivalent but smaller state space:
  - A number of possibilities
  - Currently focusing on a state space that includes for each period:
    - Remaining patient visit slots
    - Remaining or intervals
    - Number of procedures
    - Number of procedures that can be delayed

Approximate Dynamic Programming Solution Approach

- **Forward solving**
- **Train neural network to estimate value of each state:**
  - **Not trivial**
  - **Training method**
  - **Activation method**
  - **Network structure**
- **In progress!!!**

Questions, Comments & Suggestions