Long Term Workforce Planning BC Nurse Population

Based on work of
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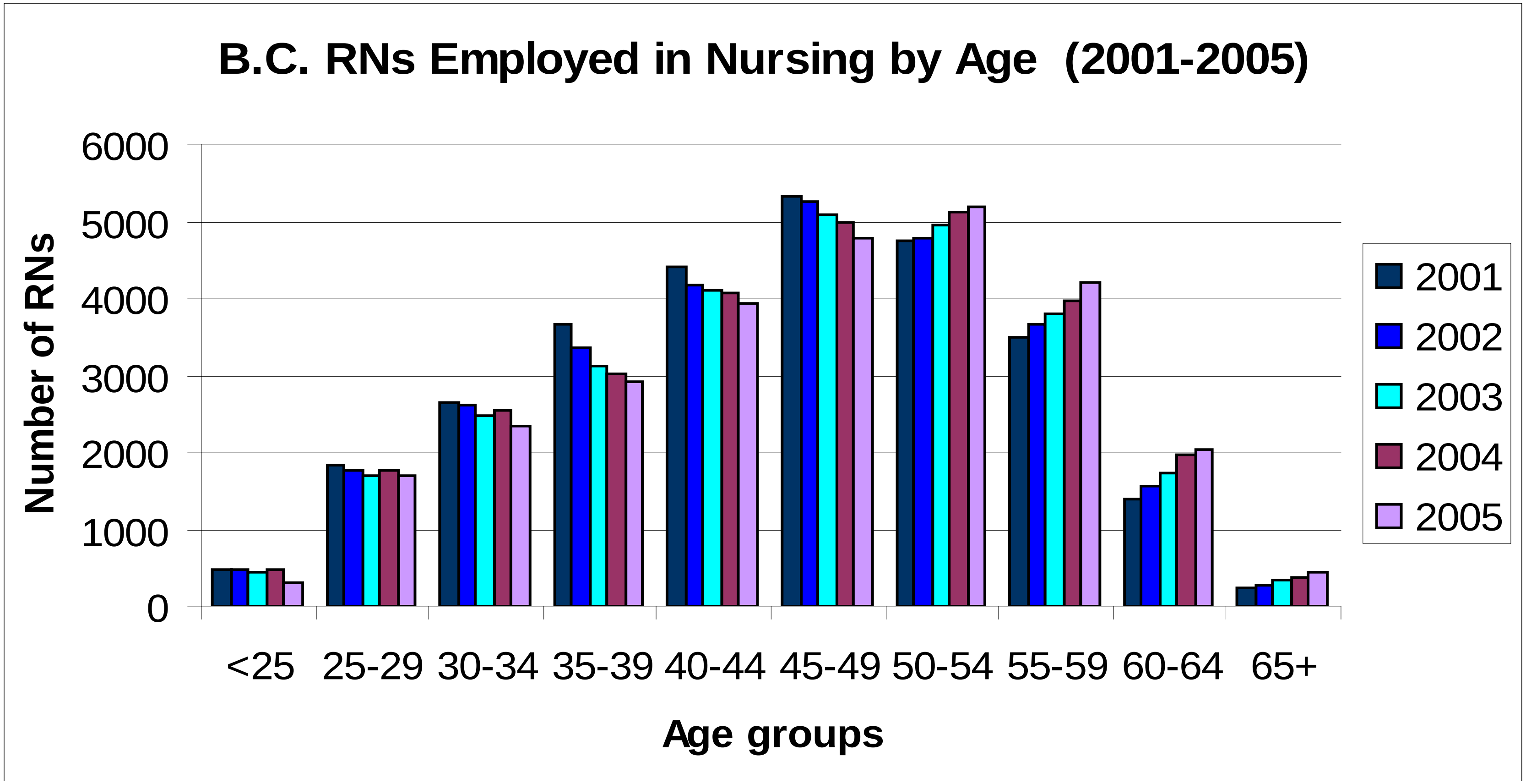
Background

- Workforce planning, training and regulation is **the** dominant immediate and long term issue for policy makers, managers, and clinical organizations.
  Listening for Direction: A national consultation on health services and policy issues
- Registered nurses account for just over one-third of the health workforce.
- Today's decision have long term implications.
- Decisions in the 1990's:
  - decrease education seats,
  - decrease nurse leadership
- In 2001, the CNA president noted "Canada should be graduating about 10,000 nurses annually to replenish the workforce in the next 10 years".

Background



Source: Canadian Institute for Health Information. (2006). Workforce Trends of Registered Nurses in Canada, 2005.

Planners Require

- **Precise** short and long term plans that provide the annual number of:
  - nursing education seats
  - nurses to recruit and at what level
  - nurses and managers to promote
- Models:
  - Inputs and assumptions can be varied and implications seen
- Flexible **unified** frameworks that apply to any workforce:
  - Regional
  - Provincial
  - National
  - Sub-specialty

Commonly Used Approach to Health Workforce Planning

- Develop a plan
- Project or simulate
- Determine if needs are met
- Revise and repeat
- Limitations
  - Tedious
  - Sub-optimal
  - Not suitable for “what if?” analyses

Our Approach

- A flexible **computer-based** optimization model that provides a minimum cost **health human resource plan** that achieves workforce targets over a multi-year planning horizon
- LP Based
- Formulated in Excel and solved using the Frontline solver add on

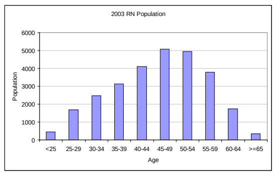
A Sample Plan

	Number admitted		Number of recruits		Number promoted	
Period	Student (year 1)	Student (year 3)	Direct Care Nurse	Entry level management	Direct Care Nurse - Entry level management	Entry level management - Senior level management
2007	1116	139	4953	0	339	70
2008	1294	161	837	201	0	34
2009	1502	187	854	118	0	28
2010	1742	217	873	154	0	31
2011	2021	252	1013	190	0	42
2012	2344	292	1175	214	0	52
2013	2719	339	1363	258	0	62
2014	3154	393	1208	255	0	58
2015	3158	456	1034	263	0	58
2016	3026	529	820	268	0	57
2017	2784	699	565	277	0	59
2018	2561	922	500	43	195	61
2019	2356	1218	500	0	284	61
2020	2168	1491	500	0	301	62
2021	2049	1734	500	10	300	62

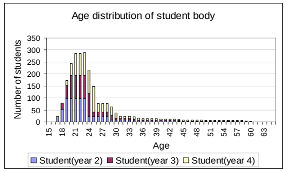
Model Overview

Data:

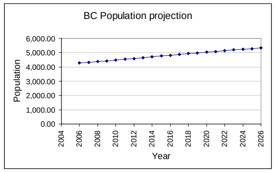
- Nurse workforce size



- Student body



- Population projection



Assumptions:

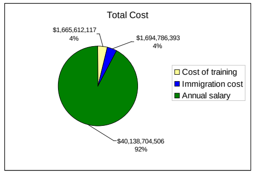
- Attrition rates
- Nurse/Pop.
- Costs

Run model:

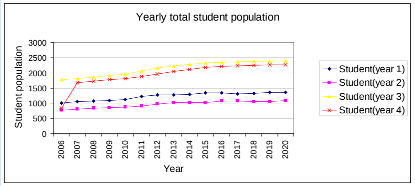
- Minimum cost plan

Outputs:

- Optimum costs



- Yearly student population



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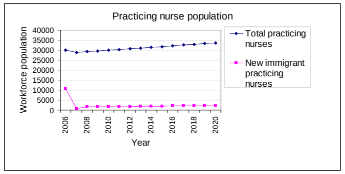

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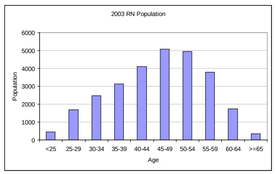

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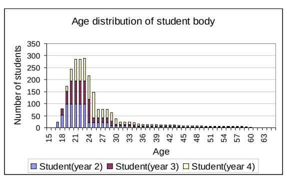

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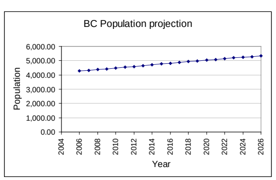
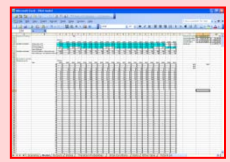


Assumptions:

- Attrition rates
- Nurse/Pop.
- Costs

Run model:

- Minimum cost plan



Outputs:

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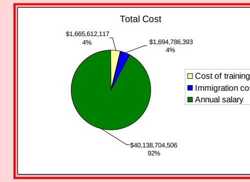

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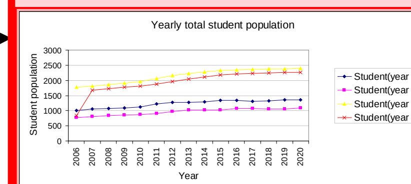

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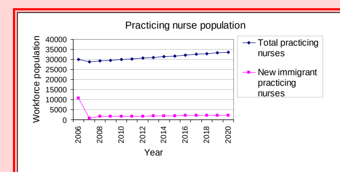

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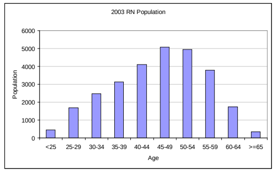

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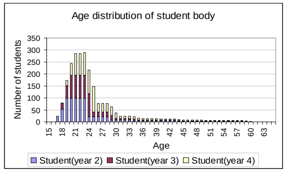

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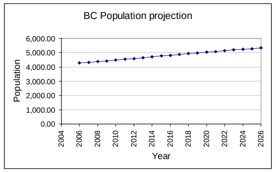
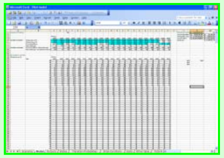


Assumptions:

- Attrition rates
- Nurse/Pop.
- Costs

Run model:

- Minimum cost plan



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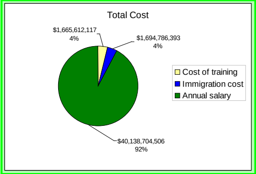
- Optimum costs



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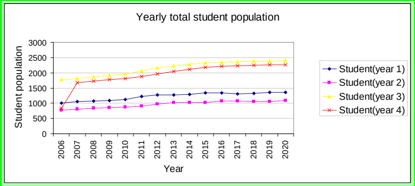

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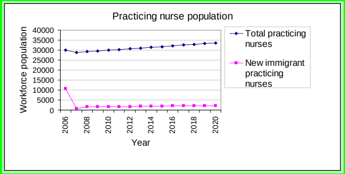
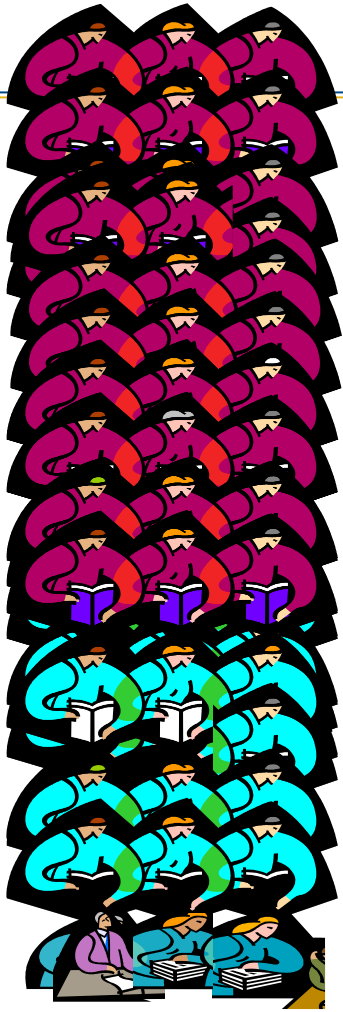


Scope

- Registered Nurses in British Columbia
- 20 year planning horizon
- Decisions made once each year
- Ages 17 – 65+
- Full time equivalent basis

Workforce Flowchart



Student(year 1)

Student(year 2)

Student(year 3)

Student(year 4)

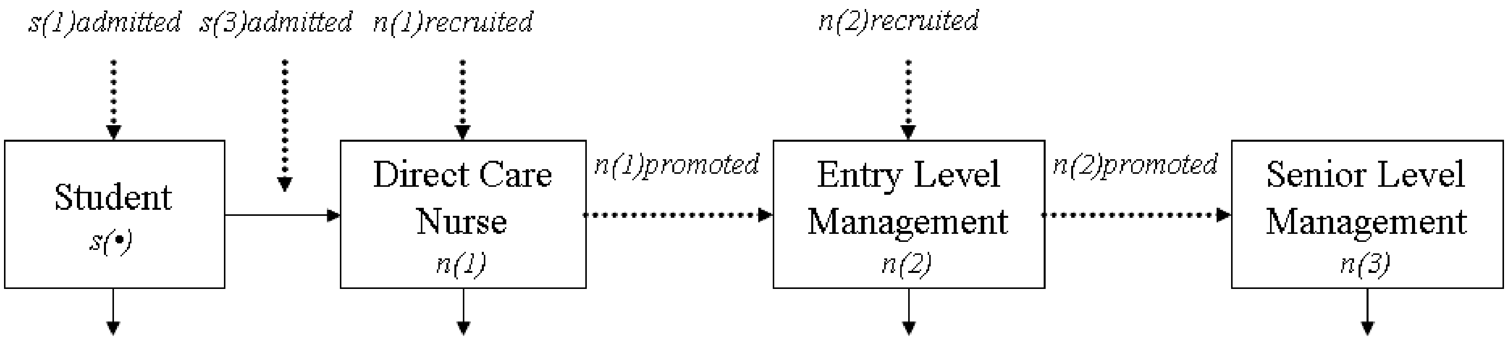
Direct Care Nurse

Entry Level Management

Senior Level Management

Cost of education
Do other work/retire
New students/recruits

Workforce flow again



Model

- Decision Variables:

In each year

- How many { Students(year 1) / Students(year 3) } to admit
- How many { Direct care nurses / Entry level management } to recruit
- How many { Direct care nurses / Entry level management } to promote

Model

- This model tracks the number of:

Students(year 1)
Students(year 2)
Students(year 3)
Students(year 4)
Practicing nurses
Nurse leaders
Senior nurse leaders

of age *i* that are in the system in year *j*

Model

Minimize:

Cost of training + Recruitment cost + Salary

In order to:

- Have sufficient resources (FTEs) to achieve quality of care targets.
- Achieve balance of “recruited” and BC educated nurses.
- Only promote nurses after they have been in their position a specified number of years.

Data Sources

- **Costs:**
  - Education:
    - Student (annual) (1)
    - Management training (one shot) (1)
  - Recruitment and turnover cost (2)
  - Salaries (by level) (3)
- **Continuation and attrition rates:**
  - Attrition rates (4), (5)
  - Age distribution (6), (7), (8)
  - Probability of continuing the degree (6), (9)
  - Probability of passing the RN exam (7)
  - Probability of leaving BC after graduation (7)
  - FTE per full time person per age per experience time in position (7)
- **Initial Conditions:**
  - Distribution of current workforce by position (8)
  - Ratio of RN to population (8)
  - BC population projections (11)

(1) Ministry of Advanced Education
(2) Weber (2005)
(3) BCNU
(4) Kazanjian (1986)
(5) O'Brien-Pallas et al. (2003)
(6) UBC School of Nursing (2006)
(7) CRNBC (2005)
(8) CIHI (2005)
(9) Pringle and Green (2005)
(10) CIHI (2005)
(11) BC STATS (2006)

Data

Variables	Notation	Description
Probabilities	$Ps(1)_i$, $Ps(3)_i$	Probability that a student admitted into the program is of age *i*
	$Prn(1)_i$, $Prn(2)_i$	Age distribution of nurses recruited
	$Ppn(1)_i$, $Ppn(2)_i$	Age distribution of nurses promoted
	Pcontinuing(1), Pcontinuing(2), Pcontinuing(3), Pcontinuing(4)	Probability of continuing in education
	Ppass	Probability of passing the provincial exam
	Pstay	Probability of practicing in the province
	$P\_retire(1)_i$, $P\_retire(2)_i$, $P\_retire(3)_i$	Attrition rate of nurses by age *i*
Initial conditions	$initial\_s(2)_i$, $initial\_s(3)_i$, $initial\_s(4)_i$	Number of students of age *i* in the first period of the model
	$initial\_n(1)_i$, $initial\_n(2)_i$, $initial\_n(3)_i$	Number of nurses of age *i* in the first period of the model
	$pfraction(1)_x$, $pfraction(2)_x$, $pfraction(3)_x$	Initial fraction of workers that have been in their position at least *x* years
Costs	*tsCost*	Cost of funding a university seat per year
	tn(2)Cost, tn(3)Cost	Cost of promoting a nurse into a managerial position
	$rn(1)Cost_j$, $rn(2)Cost_j$	Recruitment cost for each nurse in year *j*
	sn(1)Cost, sn(2)Cost, sn(3)Cost	Annual salaries
Bounds	$mins(1)_j$, $mins(3)_j$	Lower bound on the number of students admitted into the programs in year *j*
	$maxs(1)_j$, $maxs(3)_j$	Upper bound on the number of students admitted into the programs in year *j*
Demand	$BCpop_j$	Population projection for year *j*
	$n(1)ratio_j$, $n(2)ratio_j$, $n(3)ratio_j$	Minimum ratios of nurses to meet population demand in year *j*

Student admission and nurse demand constraints

$$\max s(1)_j \geq s(1)admitted_j \geq \min s(1)_j \quad \forall j \quad (21)$$

$$\max s(3)_j \geq s(3)admitted_j \geq \min s(3)_j \quad \forall j \quad (22)$$

$$\sum_i FTE(n(1)_{i,j}) \geq \frac{BCpop_j}{n(1)ratio_j} \quad \forall j \quad (23)$$

$$\sum_i FTE(n(2)_{i,j}) \geq \frac{\sum_i FTE(n(1)_{i,j})}{n(2)ratio} \quad \forall j \quad (24)$$

$$\sum_i FTE(n(3)_{i,j}) \geq \frac{\sum_i FTE(n(1)_{i,j})}{n(3)ratio} \quad \forall j \quad (25)$$

Full Time Equivalency

- Important practical consideration
- Not all nurse work full time
  - Maternity leave
  - Other leaves
  - Reduced productivity when starting out (ratio)
- FTE definition for maternity leave

$$FTE(n(\bullet)_{i,j})_{pl} = n(\bullet)_{i,j} * (1 - Fertility\_rate_i * female\_ratio * Maternity\_leave/12)$$

Balance Constraints

- Balance First and Third Year students

$$s(1)admitted_j \geq s(3)admitted_j \qquad \forall j \quad (26)$$

- Limit number of recruits by number of graduating students

$$\sum_i initial\_s(4)_i * Pcontinuing(4) * Ppass * Pstay \geq n(1)recruited_j \quad j = 1 \quad (27)$$

$$\sum_i s(4)_{i,j-1} * Pcontinuing(4) * Ppass * Pstay \geq n(1)recruited_j \quad \forall j \geq 2 \quad (28)$$

  - This maintains a 50-50 mix of BC trained and non-BC trained nurses
  - This ratio is arbitrary and can be modified for policy reasons

Only promote nurses with x years of experience

$$n(1)\,promoted_j \le pfraction(1)_x * \sum_i n(1)_{i,0} \qquad j = 1 \qquad (29)$$

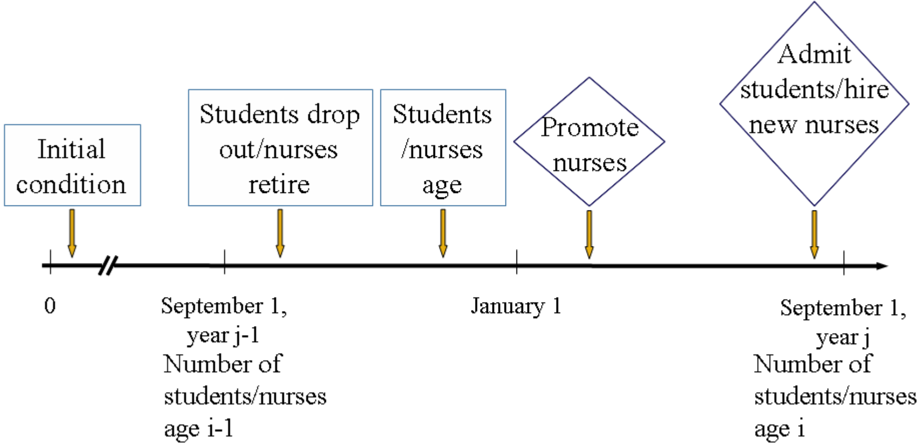
$$n(1)\,promoted_j \le \sum_i \left[n(1)_{i,0} * pfraction(1)_{x-j} * \prod_{k=0}^{j-2} (1 - P\_retire(1)_{i+k}) \right] \qquad x \ge j \ge 2 \qquad (30)$$

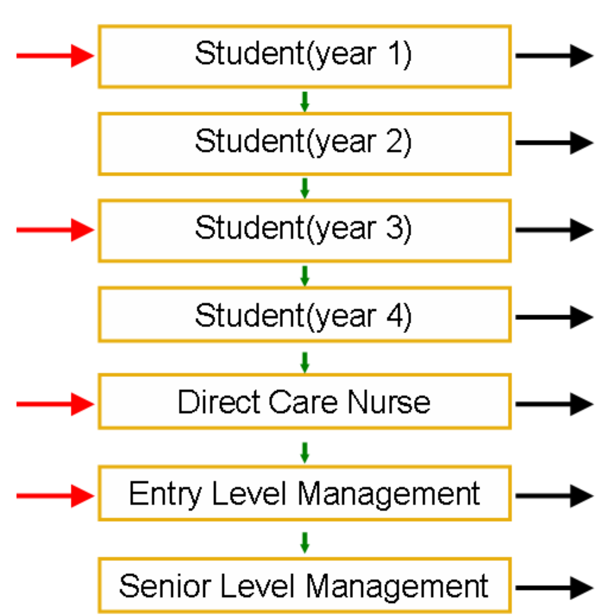
$$n(1)\,promoted_j \le \sum_i \left[n(1)_{i,j-x} * \prod_{k=0}^{x-1} (1 - P\_retire(1)_{i+k}) \right] \qquad j > x \qquad (31)$$

$$n(2)\,promoted_j \le pfraction(2)_x * \sum_i n(2)_{i,0} \qquad j = 1 \qquad (32)$$

$$n(2)\,promoted_j \le \sum_i \left[n(2)_{i,0} * pfraction(2)_{x-j} * \prod_{k=0}^{j-2} (1 - P\_retire(2)_{i+k}) \right] \qquad x \ge j \ge 2 \qquad (33)$$

$$n(2)\,promoted_j \le \sum_i \left[n(2)_{i,j-x} * \prod_{k=0}^{x-1} (1 - P\_retire(2)_{i+k}) \right] \qquad j > x \qquad (34)$$





Given $65 \geq i \geq 16 = \text{age}$, $j = 1 \ldots N = \text{time period}$

- Total number of first year students of age i at time period $j = s(1)_{i,j}$

$$s(1)_{i,j} = s(1)admitted_j * Ps(1)_i \ \forall \ i, j$$

- Total number of second year students of age i at time period $j = s(2)_{i,j}$

$$s(2)_{i,j} = \begin{cases} initial \ s(2)_{i,j} & \text{for } j = 1, 16 \leq i \\ s(1)_{i-1,j-1} * Pcontinuing(1) & \text{for } 2 \leq j \leq N, 16 \leq i < 65 \\ [s(1)_{i-1,j-1} + s(1)_{i,j-1}] * Pcontinuing(1) & \text{for } 2 \leq j \leq N, i = 65 \end{cases}$$

- Total number of third year students of age i at time period $j = s(3)_{i,j}$

$$s(3)_{i,j} = \begin{cases} initial \ s(3)_{i,j} + s(3)admitted_j * Ps(3)_i & \text{for } j = 1, 16 \leq i \\ s(2)_{i-1,j-1} * Pcontinuing(2) + s(3)admitted_j * Ps(3)_i & \text{for } 2 \leq j \leq N, 16 \leq i < 65 \\ [s(2)_{i-1,j-1} + s(2)_{i,j-1}] * Pcontinuing(2) & \\ \ + s(3)admitted_j * Ps(3)_i & \text{for } 2 \leq j \leq N, i = 65 \end{cases}$$

- Total number of fourth year students of age i at time period $j = s(4)_{i,j}$

$$s(4)_{i,j} = \begin{cases} initial \ s(4)_{i,j} & \text{for } j = 1, 16 \leq i \\ s(3)_{i-1,j-1} * Pcontinuing(3) & \text{for } 2 \leq j \leq N, 16 \leq i < 65 \\ [s(3)_{i-1,j-1} + s(3)_{i,j-1}] * Pcontinuing(3) & \text{for } 2 \leq j \leq N, i = 65 \end{cases}$$

- Total number of practicing nurses of age i at time period $j = n(1)_{i,j}$

$$
n(1)_{i,j} = \begin{cases}
\text{initial } n(1)_{i,j} & \\
\quad + [n(1)recruited_j - n(1)promoted_j] * Pn(1)_i & \text{for } j = 1, 16 \leq i \\
n(1)_{i-1,j-1} * (1 - Pretire(1)_{i-1}) & \\
\quad + s(4)_{i-1,j-1} * Pcontinuing(4) * Ppass * Pstay & \\
\quad + [n(1)recruited_j - n(1)promoted_j] * Pn(1)_i & \text{for } 2 \leq j \leq N, 16 \leq i < 65 \\
n(1)_{i-1,j-1} * (1 - Pretire(1)_{i-1}) & \\
\quad + n(1)_{i,j-1} * (1 - Pretire(1)_i) & \\
\quad + s(4)_{i-1,j-1} * Pcontinuing(4) * Ppass * Pstay & \\
\quad + s(4)_{i,j-1} * Pcontinuing(4) * Ppass * Pstay & \\
\quad + [n(1)recruited_j - n(1)promoted_j] * Pn(1)_i & \text{for } 2 \leq j \leq N, i = 65
\end{cases}
$$

- Total number of nurse leaders of age i at time period $j = n(2)_{i,j}$

$$
n(2)_{i,j} = \begin{cases}
\text{initial } n(2)_{i,j} & \\
\quad + n(1)promoted_j * Pn(1)_i & \\
\quad + [n(2)recruited_j - n(2)promoted_j] * Pn(2)_i & \text{for } j = 1, 16 \leq i \\
n(2)_{i-1,j-1} * (1 - Pretire(2)_{i-1}) & \\
\quad + n(1)promoted_j * Pn(1)_i & \\
\quad + [n(2)recruited_j - n(2)promoted_j] * Pn(2)_i & \text{for } 2 \leq j \leq N, 16 \leq i < 65 \\
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\quad + n(2)_{i,j-1} * (1 - Pretire(2)_i) & \\
\quad + n(1)promoted_j * Pn(1)_i & \\
\quad + [n(2)recruited_j - n(2)promoted_j] * Pn(2)_i & \text{for } 2 \leq j \leq N, i = 65
\end{cases}
$$

- Total number of senior nurse leaders of age i at time period $j = n(3)_{i,j}$

$$
n(3)_{i,j} = \begin{cases}
\text{initial } n(3)_{i,j} & \\
\quad + n(2)promoted_j * Pn(2)_i & \text{for } j = 1, 16 \leq i \\
n(3)_{i-1,j-1} * (1 - Pretire(3)_{i-1}) & \\
\quad + n(2)promoted_j * Pn(2)_i & \text{for } 2 \leq j \leq N, 16 \leq i < 65 \\
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\quad + n(3)_{i,j-1} * (1 - Pretire(3)_i) & \\
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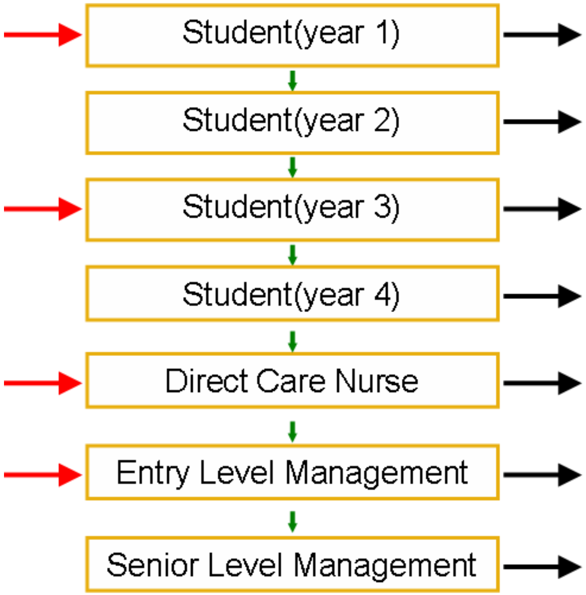


Objective function

- Training Costs

$$\sum_i \left[s(1)_{i,j} + s(2)_{i,j} + s(3)_{i,j} + s(4)_{i,j}\right] * tsCost$$
$$+ n(1)\,promoted_j * tn(2)Cost + n(2)\,promoted_j * tn(3)Cost$$

- Recruitment Costs

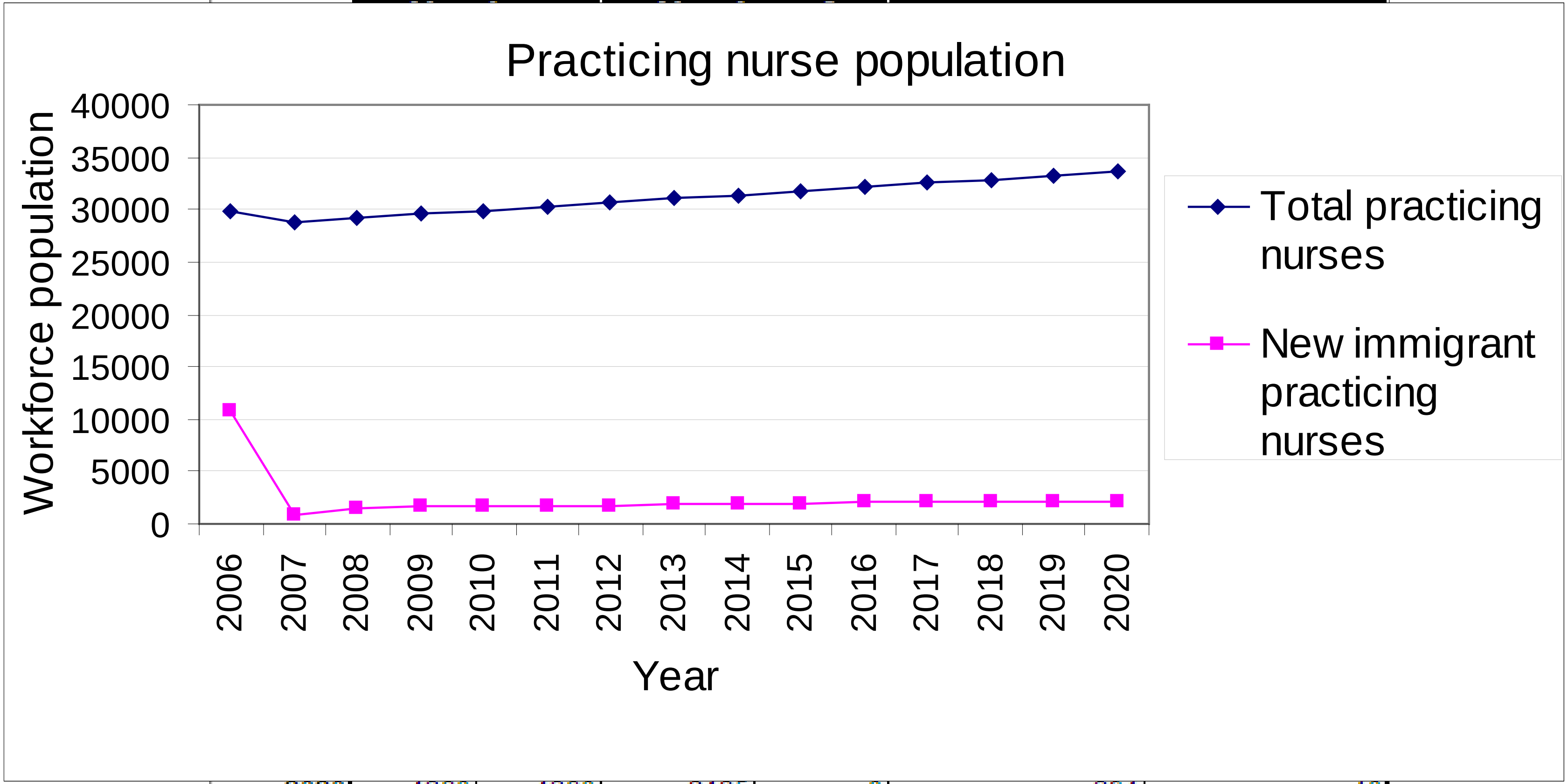
$$n(1)recruited_j * rn(1)Cost_j + n(2)recruited_j * rn(2)Cost_j$$

- Salaries

$$Annual\ Salary_j = \sum_i n(1)_{i,j} * sn(1)Cost + \sum_i n(2)_{i,j} * sn(2)Cost + \sum_i n(3)_{i,j} * sn(3)Cost$$

- These are summed over years *j*
- They ensure that equalities hold where possible so they force workforce to just meet demand (on an FTE) basis

Outputs – Baseline



2020	1360	1360	2125	0	391	40

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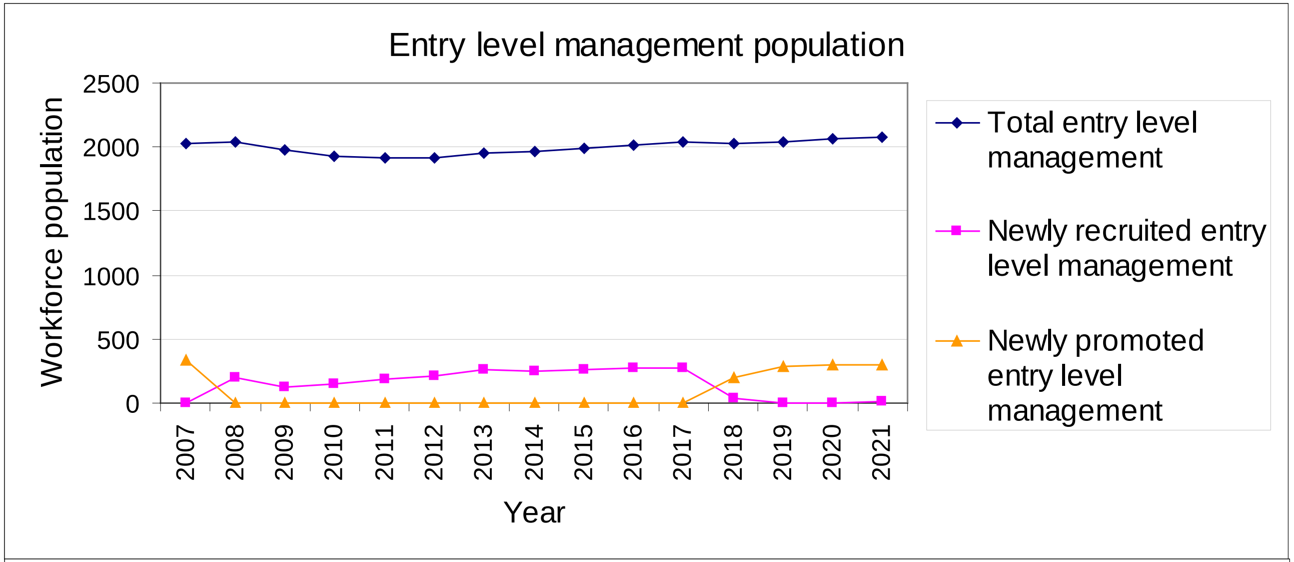
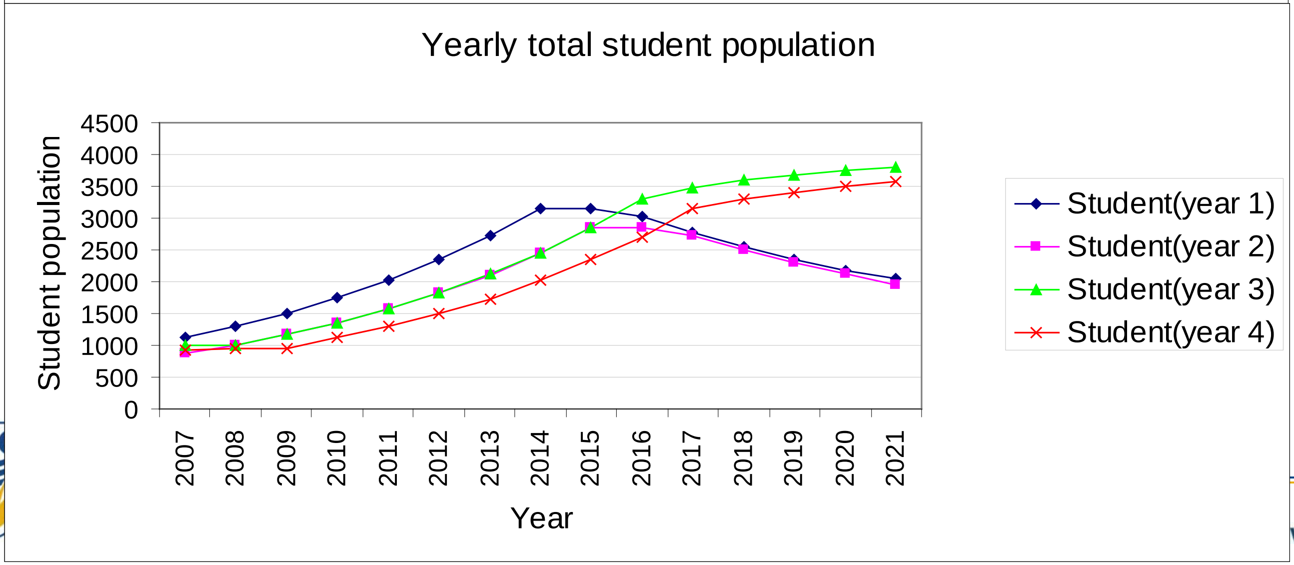
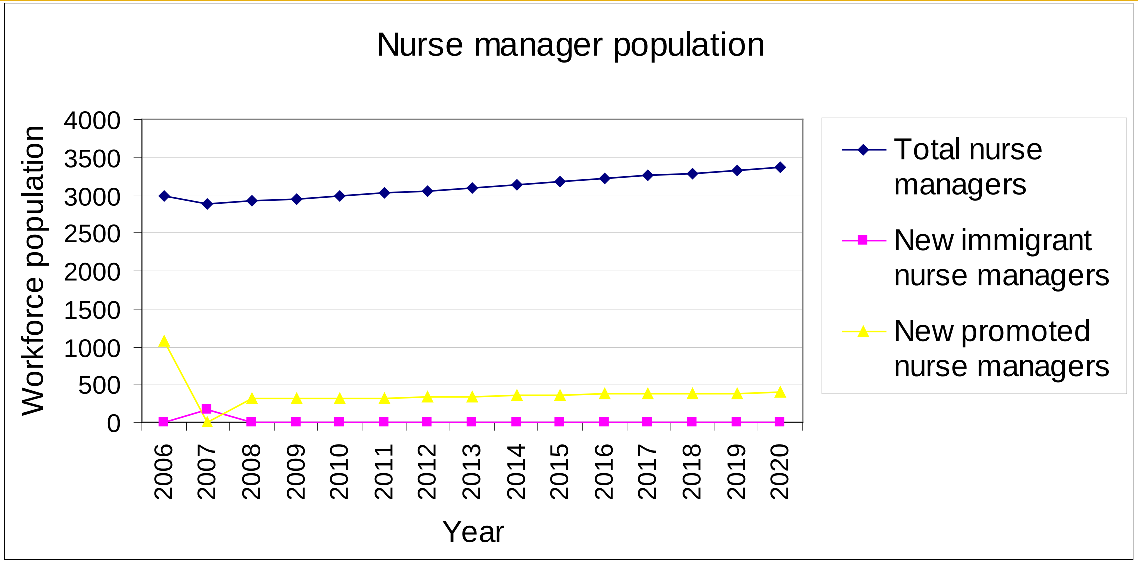
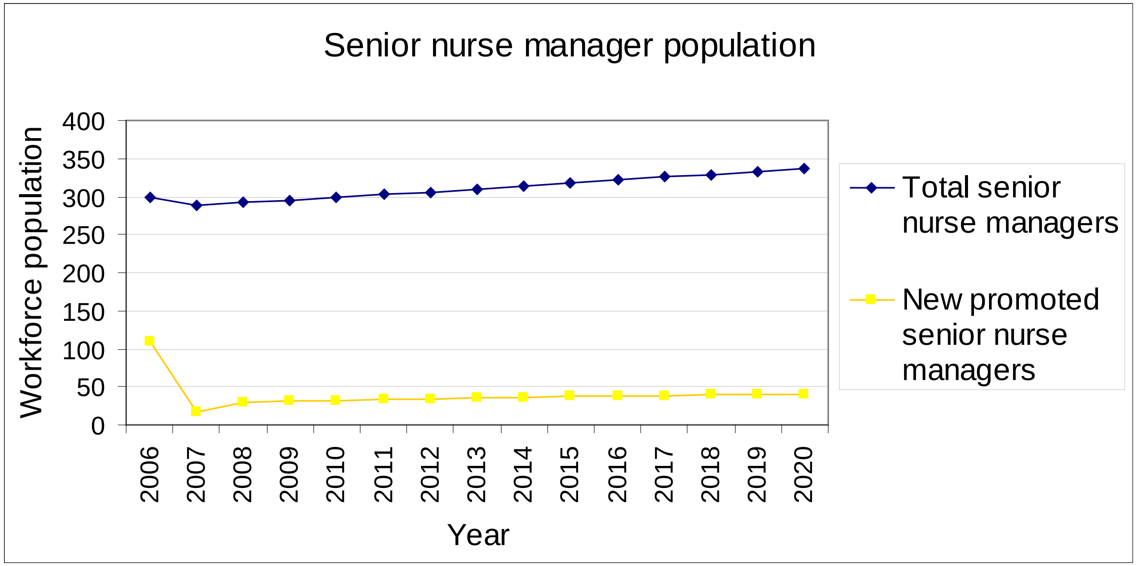




Outputs – Baseline

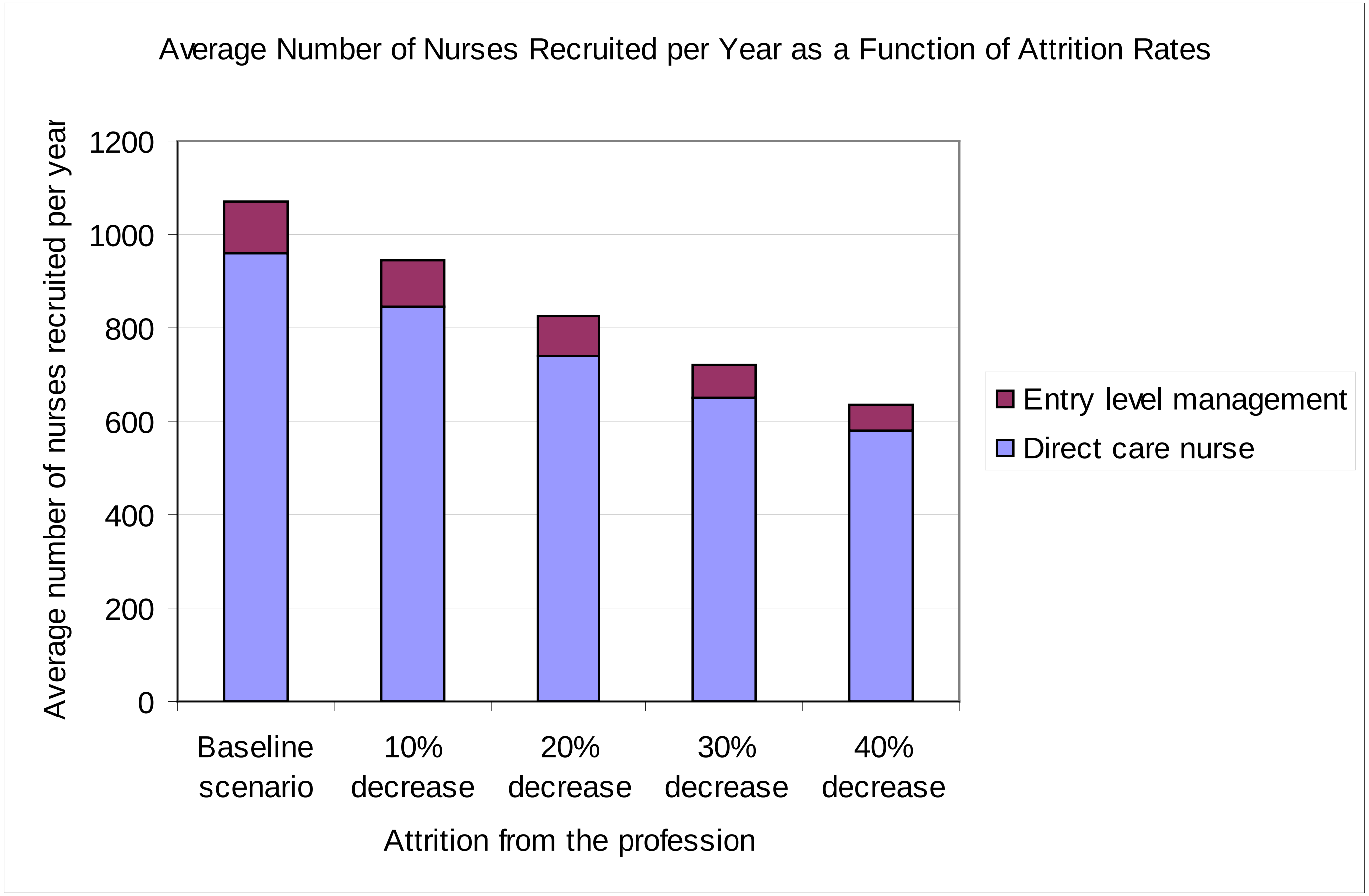




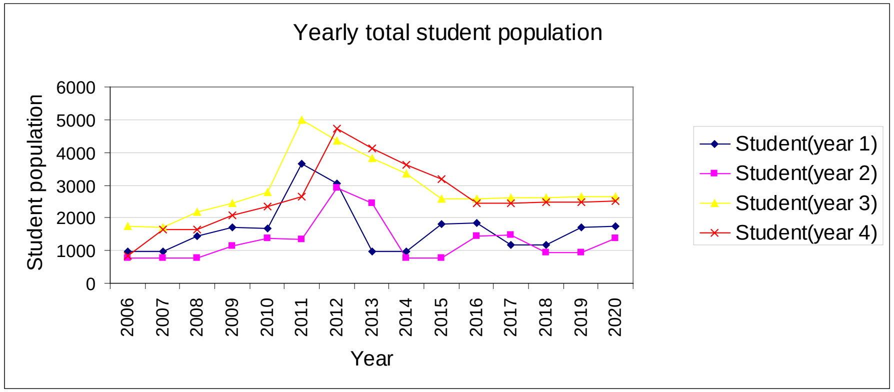
Possible Scenarios for “What if?” Analysis

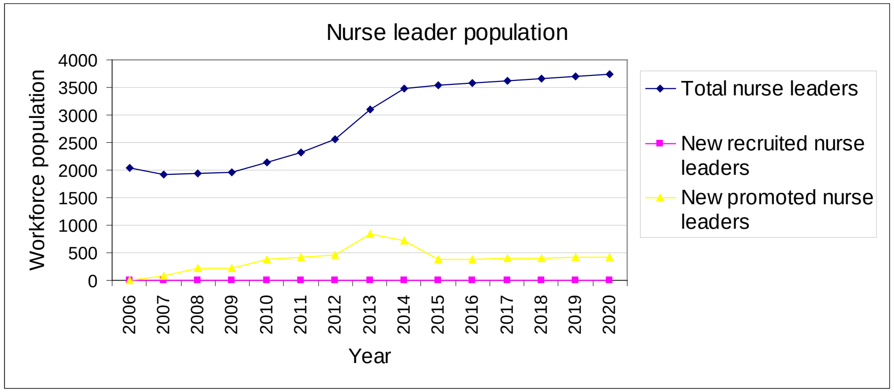
- Vary nurse to population ratio
- Vary proportion of students that continue the program after each year of study
- Vary nurse to manager ratios and nurse attrition rates
- Change maternity leave policies
- Change demand for nurses
- Change attrition rates
- …

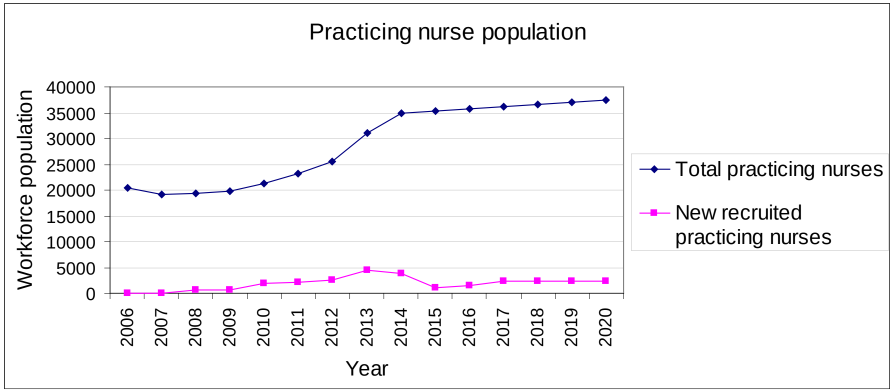
Effect of Attrition on Recruitment Volumes

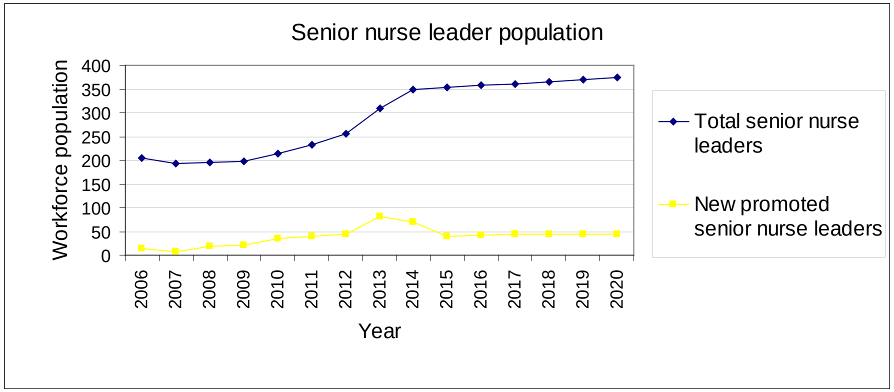


Outputs – Decreasing Nurse/Population ratios over time

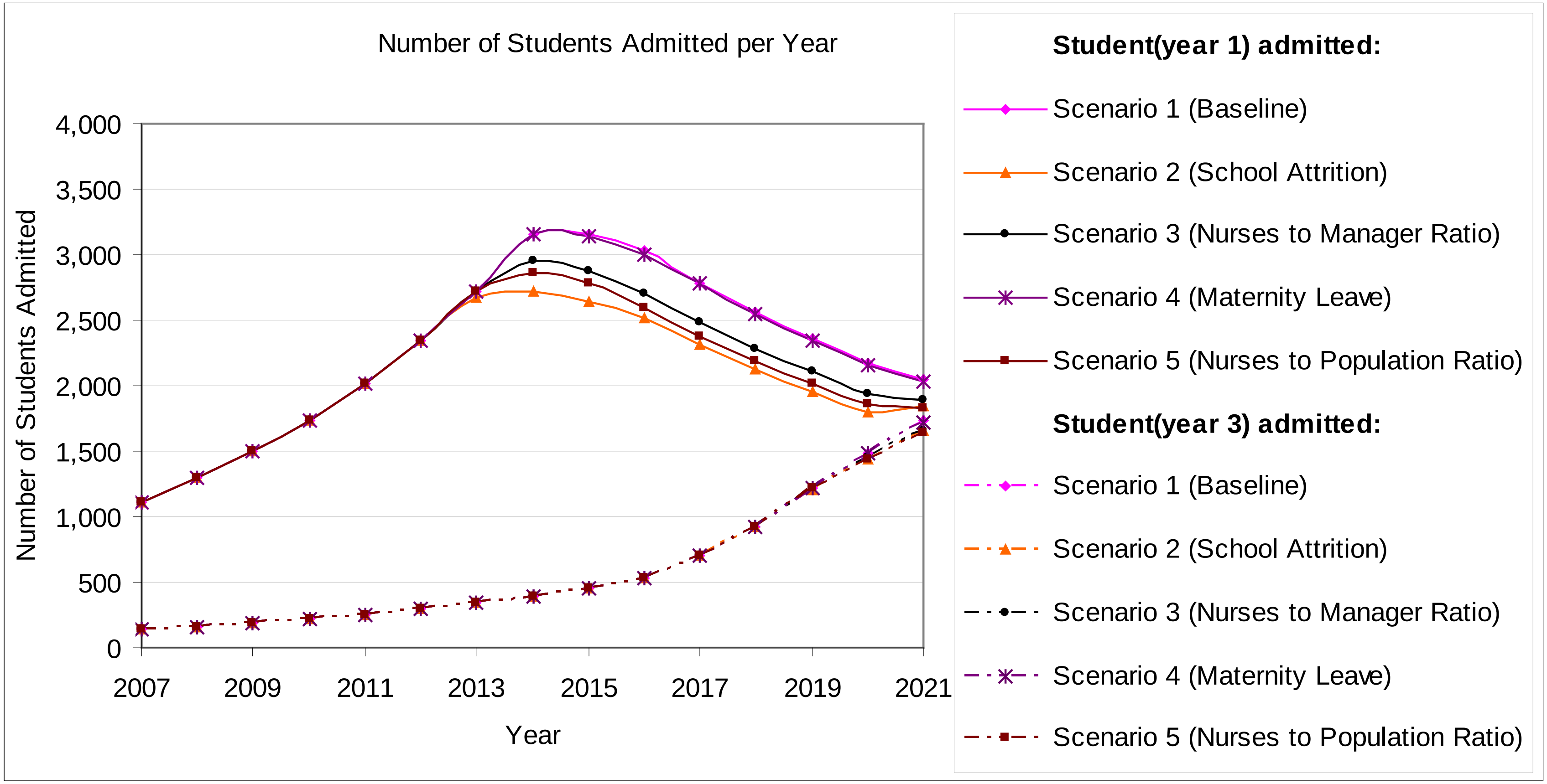








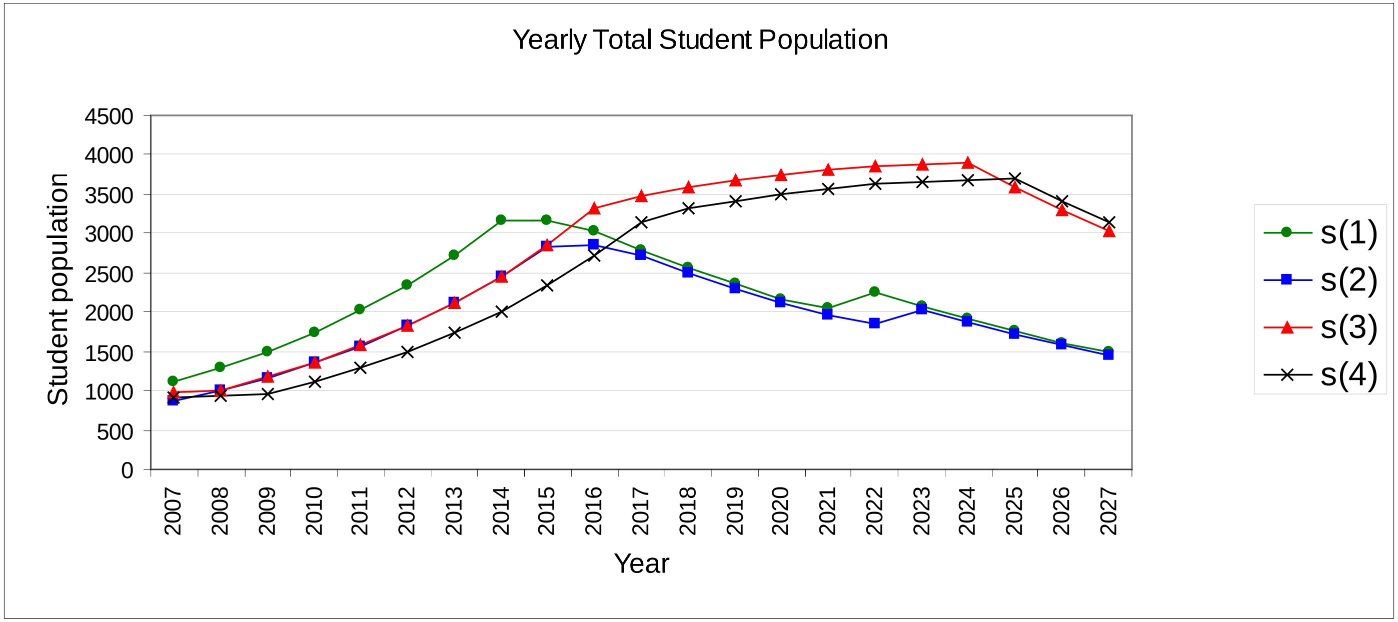
Outputs – Comparing Scenarios



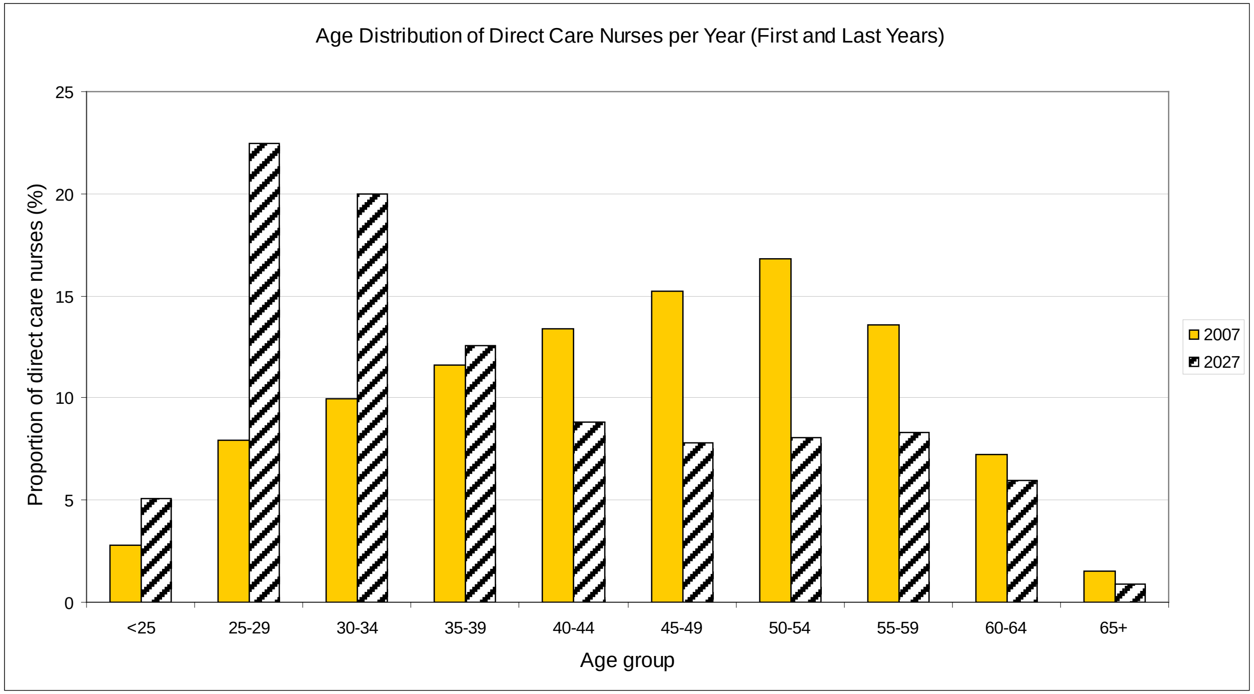
Research Challenges

- End Conditions
  - How do we ensure that finite horizon model is optimal for infinite planning horizon?
- Stochasticity
  - Changes in retirements; maternity leaves, student attrition, unfilled demand
- Feedback

Effect of End Conditions – 20 year model



Changing Age Distribution (20 year Model)



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Comments

- We have developed a tool for decision makers to examine HHR planning in the broadest context
- The modeling approach extends to other healthcare professionals or levels of granularity
- References
  - Application **- Using Operations Research to Plan the British Columbia Registered Nurses' Workforce,** Mariel S. Lavieri, Sandra Regan, Martin L. Puterman and Pamela A. Ratner, *Healthcare Policy*, 4(2) 2008: e117-e135
  - Methods **- Optimizing Nursing Human Resource Planning in British Columbia,** Mariel S. Lavieri and Martin L. Puterman, *Health Care Management Science* (accepted 2008)

CIHR Team in Operations Research for Improved Cancer Care

Strategic Planning of Radiation Therapists at the BC Cancer Agency

Greg Werker, Martin Puterman, Mike Darud

- This study is funded by the Canadian Institute of Health Research (CIHR).

BC Cancer Agency CARE & RESEARCH An agency of the Provincial Health Services Authority

Provincial Health Services Authority Province-wide solutions. Better health.

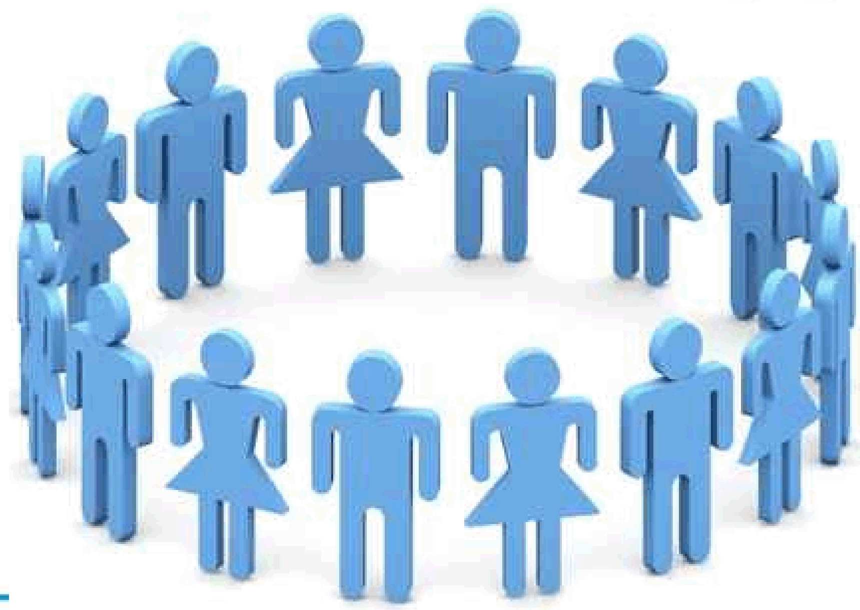
UBC Centre for Health Care Management THE UNIVERSITY OF BRITISH COLUMBIA

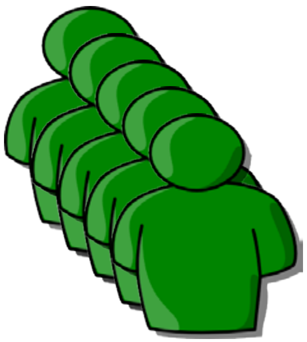
SAUDER School of Business UNIVERSITY OF BRITISH COLUMBIA

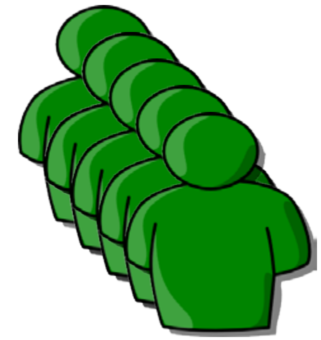
CIHR IRSC

Motivation from an HR Perspective

- RTs want more predictability, involvement
- HR push to create longer-term plan
- In practice, not so easy to do
- Currently planning done by hand

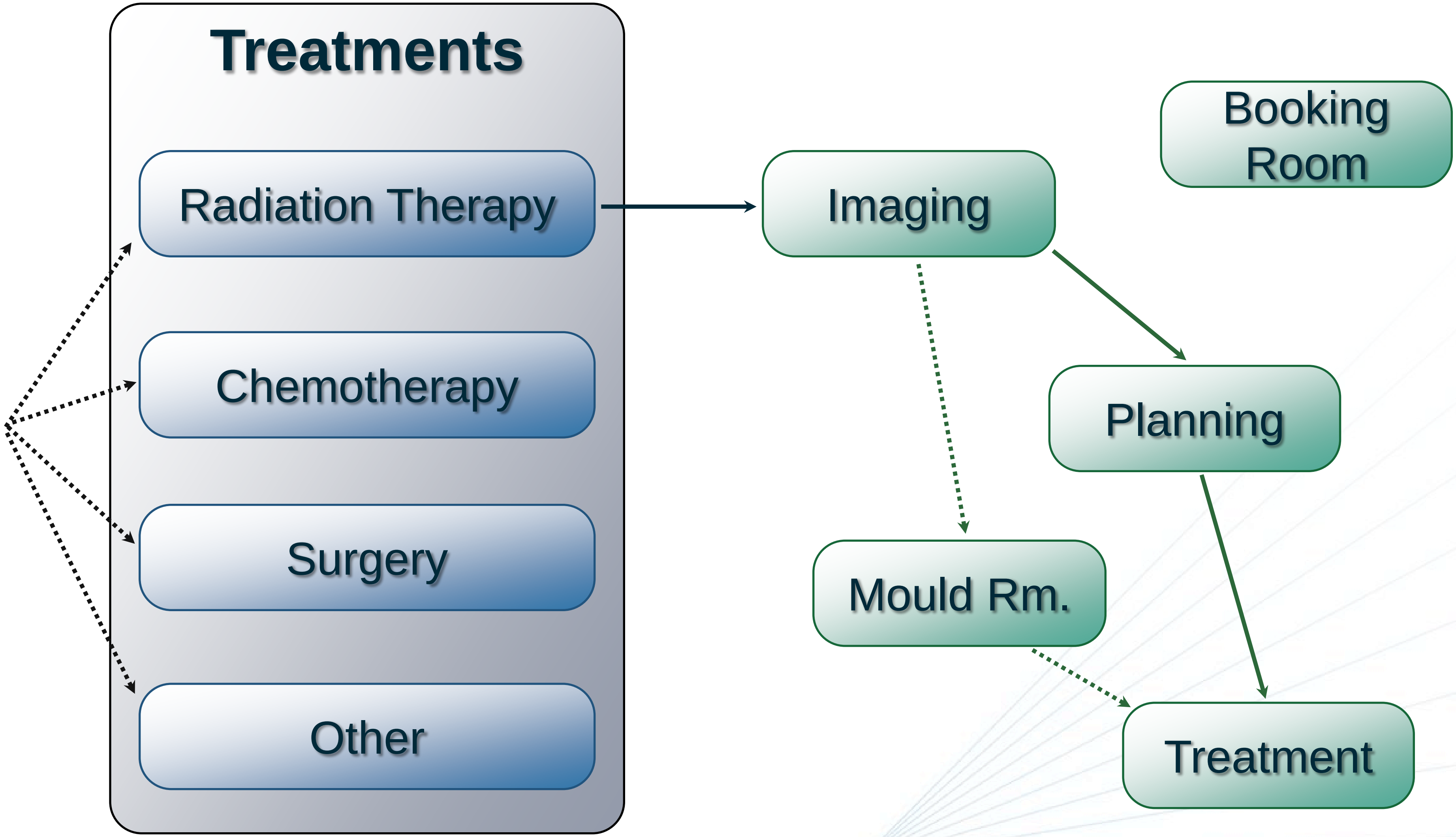






How do we create a long-term plan for all radiation therapists for the next few years?

Radiation Therapy Map



Radiation Therapy Task Areas

Mould Rm.

- Mould Rm.

Booking Room

- Booking

Treatment

- Treatment
- Sim

Imaging

- CTSim1
- CTSim2
- CTSim3

Planning

- Dos1
- Dos2
- Dos3
- Dos4

Experience

- Mould Rm.
- Booking
- Treatment
- Sim
- CTSim1
- CTSim2
- CTSim3
- Dos1
- Dos2
- Dos3
- Dos4

Sample Paths

Sample path #1

- Treatment (12)
- CTSim1 (1)
- CTSim2 (1)
- Mould Rm. (2)
- Dos1 (1)
- Dos2 (2)
- Dos3 (4)

Sample path #2

- Treatment (4)
- Sim (1)
- Treatment (8)
- CTSim1 (1)
- Mould Rm. (2)
- CTSim2 (1)
- CTSim3 (2)

Variables

Domains:

T: Therapist

A: Area

B: Area required Before

P: Period

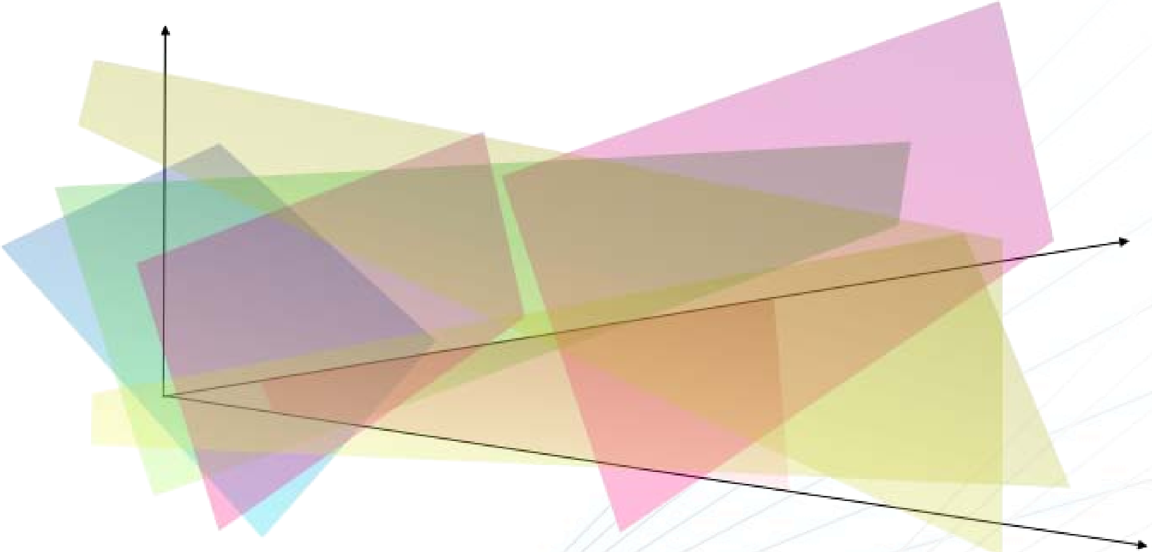
$$X_{T,A,P} = \begin{cases} 1 & \text{if } T \text{ is assigned to } A \text{ in } P \\ 0 & \text{otherwise} \end{cases}$$

$$Y_{T,A,P} = \begin{cases} 1 & \text{if } T \text{ begins a sequence in } A \text{ in } P \\ 0 & \text{otherwise} \end{cases}$$

$$H_{T,A,B,P} = \begin{cases} 1 & \text{if } T \text{ has the necessary experience in area } B \text{ for } A \text{ in } P \\ 0 & \text{otherwise} \end{cases}$$

Constraints

Initial Position
Coverage
One Area Only
Min Duration
Has Experience



Initial Position

- $INIT_{T,A}$ = 1 if *T* is initially (currently) in *A*; 0 otherwise

	A	O
1		Q0
5	[illegible]	Treat
6	[illegible]	Sim
7	[illegible]	Booking
8	[illegible]	Treat
9	[illegible]	Dos3
10	[illegible]	Treat
11	[illegible]	Dos4
12	[illegible]	Treat
13	[illegible]	Treat
14	[illegible]	CTSim3
15	[illegible]	CTSim2
16	[illegible]	Dos2
17	[illegible]	Treat
18	[illegible]	Dos3
19	[illegible]	Dos3
20	[illegible]	Treat
21	[illegible]	dos1
22	[illegible]	dos1
23	[illegible]	dos1
24	[illegible]	CTSim1
25	[illegible]	Treat

(Excel interface only displays the 1s, by showing which A each T is initially in.)

Constraint: Initial Position

$$X_{T,A,\text{“}Q0\text{”}} = INIT_{T,A} \quad \forall T, A$$

Total Requirements

- *TOTREQ$_A$* = total number therapists required in area A

	A	B
1		TOTREQ
2	NoWork	0
3	Treat	26
4	Brachy	3
5	Special	3
6	Pall	4
7	CTSim1	3
8	CTSim2	2
9	CTSim3	1
10	MR	3
11	Sim	2
12	Dos1	4
13	Dos2	2
14	Dos3	2
15	Dos4	2
16	Booking	1
17		
18	sum	58
19		

(Excel interface and GAMS model actually allow total requirements to be specified by period)

Constraint: Coverage

$$\sum_{T} X_{T,A,P} \geq TOTREQ_A \quad \forall A, P$$

Note; this is only constraint between therapists

Constraint: Therapist can work in only one area each period

$$\sum_{A} X_{T,A,P} = 1 \quad \forall T, P$$

Minumum (and Maximum) Duration

- *$MINDUR_A$* = minimum number of consecutive periods a therapist must work in an area A if begins work in that area

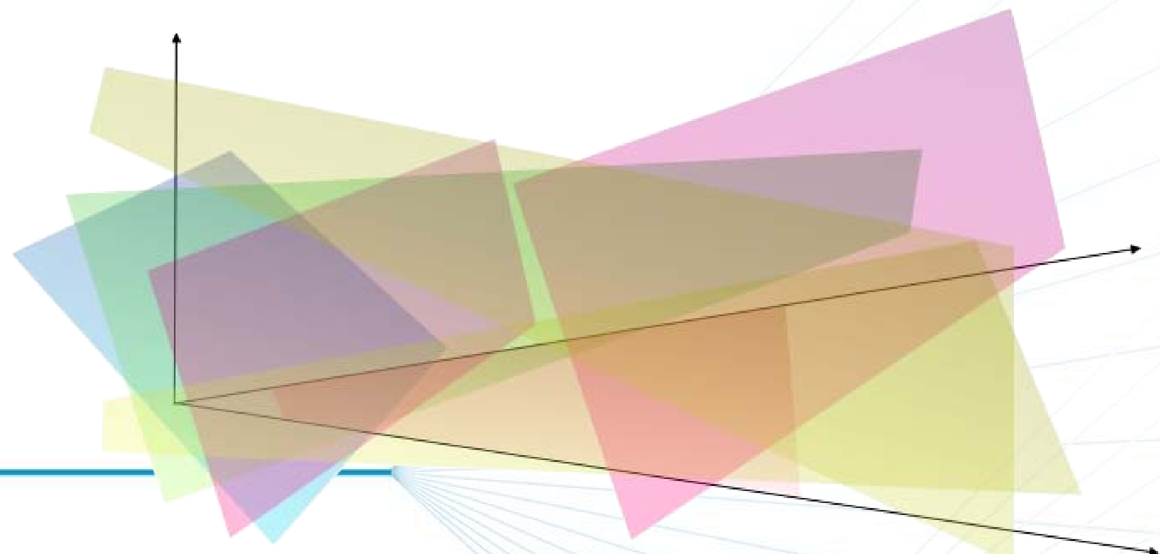
- *$MAXDUR_A$* = used in soft constraint for maximum number consecutive periods

	A	B	C	D	E
1	**Areas**	MinDur		**Areas**	MaxDur
2					
3	NoWork	0		NoWork	20
4	Treat	2		Treat	12
5	CTSim1	1		CTSim1	4
6	CTSim2	1		CTSim2	4
7	CTSim3	2		CTSim3	8
8	MR	2		MR	8
9	Sim	1		Sim	4
10	Dos1	1		Dos1	4
11	Dos2	2		Dos2	4
12	Dos3	2		Dos3	4
13	Dos4	2		Dos4	8
14	Booking	2		Booking	6

Constraint: Min Duration

$$\sum_{q=P}^{P+MINDUR_A-1} X_{T,A,q} \geq MINDUR_A * Y_{T,A,P} \quad \forall T, A, P$$

$$X_{T,A,P} - X_{T,A,P-1} \leq Y_{T,A,P} \quad \forall T, A \quad \forall P > 0$$



Total Requirements

- $STEXP_{T,B}$ = starting experience levels for each therapist in area B

	A	B	C	D	E	F	G	H	I	J	K	L	M
1		Treat	Brachy	Special	Pall	CTsim1	CTsim2	CTsim3	MR	Sim	Dos1	Dos2	Dos3
5	[illegible]	12											
6	[illegible]	12								1			
7	[illegible]	12											
8	[illegible]	12							2	1			
9	[illegible]	12									1	2	4
10	[illegible]	12											
11	[illegible]	12									1	2	4
12	[illegible]	12											
13	[illegible]	12								1			
14	[illegible]	12				1	1	3		1			
15	[illegible]	12				1	1	3	2				
16	[illegible]	12				1	1	3			1	1	
17	[illegible]	12											
18	[illegible]	12							2	1	1	2	4
19	[illegible]	12				1	1	3		1	1	2	2
20	[illegible]	12											

(12 is the maximum required quarters of treatment experience; similarly 1 for CTSim1, 1 for CTSim2, 3 for CTSim3...)

Total Requirements

- *$EXP_{A,B}$* = experience required in area B *before* being allowed to work in area A

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1		Treat	Brachy	Special	Pall	CTSim1	CTSim2	CTSim3	MR	Sim	Dos1	Dos2	Dos3	Dos4	Booking
2	Treat														
3	Brachy	12													
4	Special	4													
5	Pall	2													
6	CTSim1	12													
7	CTSim2	12				1									
8	CTSim3	12				1	1								
9	MR	4													
10	Sim	4													
11	Dos1	12													
12	Dos2	12									1				
13	Dos3	12									1	2			
14	Dos4	12									1	2	4		
15	Booking	6													
16															

(e.g., to work in Dos3, one must have 12 quarters treatment experience, 1 quarter in Dos1, and 2 quarters in Dos2)

Constraint: Has Experience

$$H_{T,A,B,P} * EXP_{A,B} \leq STEXP_{T,B} + \sum_{q=1}^{P} X_{T,B,q}$$

$$STEXP_{T,B} + \sum_{q=1}^{P} X_{T,B,q} - (EXP_{A,B} - 0.5) \leq H_{T,A,B,P} * M$$

$$X_{T,A,P} \leq H_{T,A,B,P}$$

all three constraints are defined...

∀ *T*, *A*, P and B (for which *B* is required for *A*)

Initial Position

$$X_{T,A,\text{“}Q0\text{”}} = INIT_{T,A} \quad \forall T, A$$

Coverage

$$\sum_{T} X_{T,A,P} \geq TOTREQ_A \quad \forall A, P$$

One Area Only

$$\sum_{A} X_{T,A,P} = 1 \quad \forall T, P$$

Min (and Max) Duration

$$\sum_{q=P}^{P+MINDUR_A-1} X_{T,A,q} \geq MINDUR_A * Y_{T,A,P} \quad \forall T, A, P$$

$$X_{T,A,P} - X_{T,A,P-1} \leq Y_{T,A,P} \quad \forall T, A \quad \forall P > 0$$

Has Experience

$$H_{T,A,B,P} * EXP_{A,B} \leq STEXP_{T,B} + \sum_{q=1}^{P} X_{T,B,q}$$

$$STEXP_{T,B} + \sum_{q=1}^{P} X_{T,B,q} - (EXP_{A,B} - 0.5) \leq H_{T,A,B,P} * M$$

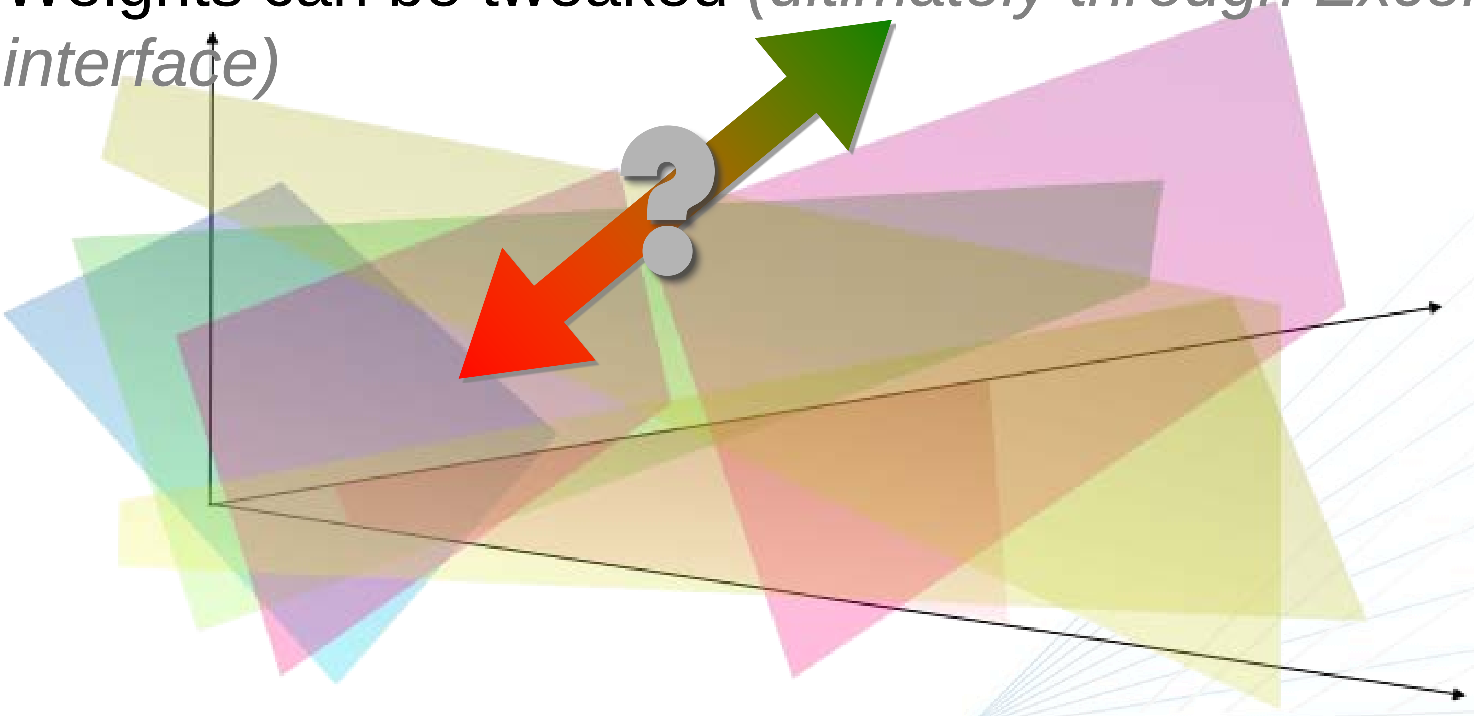
$$X_{T,A,P} \leq H_{T,A,B,P}$$

the above 3 constraints are defined...

∀ *T*, *A*, *B*, *P* : *B* is required for *A*

Objective Function

- Possibly just a constant – i.e find a feasible solution, or
- A combination of penalties and rewards – goal is to violate as few soft constraints as little as possible
- Weights can be tweaked *(ultimately through Excel interface)*



More Components

- **Additional functionality:**
  - New hires
  - Part-time therapists
  - Maternity leave; sick leave
- **Soft constraints:**
  - Forced assignments
  - Max duration

Excel Input

	A	M	N	O	P	Q	R	S
1		Q1	Q2	Q3	Q4	Q5	Q6	Q7
2	[illegible]	Dos3	O	O	O	O	O	X
3	[illegible]	O	O	O	O	O	O	O
4	[illegible]	Dos3	O	O	O	O	O	O
5	[illegible]	X	X	O	O	O	O	O
6	[illegible]	O	O	O	Dos2	O	O	O
7	[illegible]	O	O		X	X	X	X
8	[illegible]	O			O	O	O	O
9	[illegible]	O			O	O	O	O
10	[illegible]	O			MR	O	O	O
11	[illegible]	O			O	O	O	O
12	[illegible]	X			X	O	O	O
13	[illegible]	O			O	O	O	O
14	[illegible]	O	O	O	O	O	O	O
15	[illegible]	O	O	O	O	O	O	O
16	[illegible]	O	X	X	X	X	O	O
17	[illegible]					O		
18	[illegible]					O		

O
X
Treat
CTSim1
CTSim2
CTSim3
MR
Sim

Staff Planning Model

Run Model

(model will automatically be saved first)

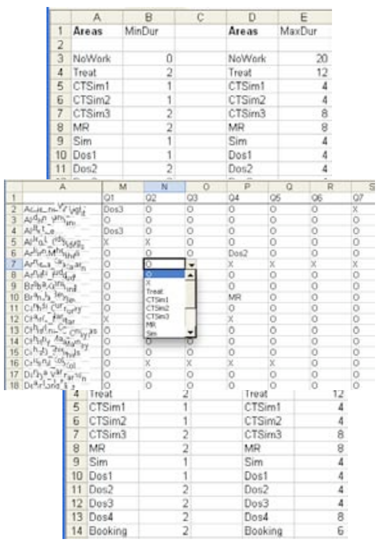
	A	B	C	D	E	F	G	H	I
3		Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8
4	NoWork	22.00	22.00	21.50	21.00	22.00	21.00	19.50	21.50
5	Treat	36.18	36.18	36.04	36.70	36.00	36.10	36.84	36.84
6	CTSim1	3.00	3.84	3.24	3.50	3.08	3.00	3.00	3.00
7	CTSim2	2.00	2.00	2.00	2.00	2.00	2.00	2.50	2.50
8	CTSim3	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
9	MR	3.00	3.00	3.50	3.60	3.10	3.34	5.34	3.34

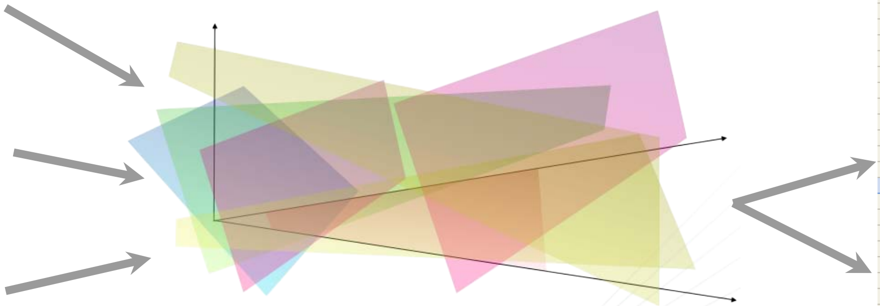
	A	B	C	D	E
1	**Areas**	MinDur		**Areas**	MaxDur
2					
3	NoWork	0		NoWork	20
4	Treat	2		Treat	12
5	CTSim1	1		CTSim1	4
6	CTSim2	1		CTSim2	4
7	CTSim3	2		CTSim3	8
8	MR	2		MR	8
9	Sim	1		Sim	4
10	Dos1	1		Dos1	4
11	Dos2	2		Dos2	4
12	Dos3	2		Dos3	4
13	Dos4	2		Dos4	8
14	Booking	2		Booking	6

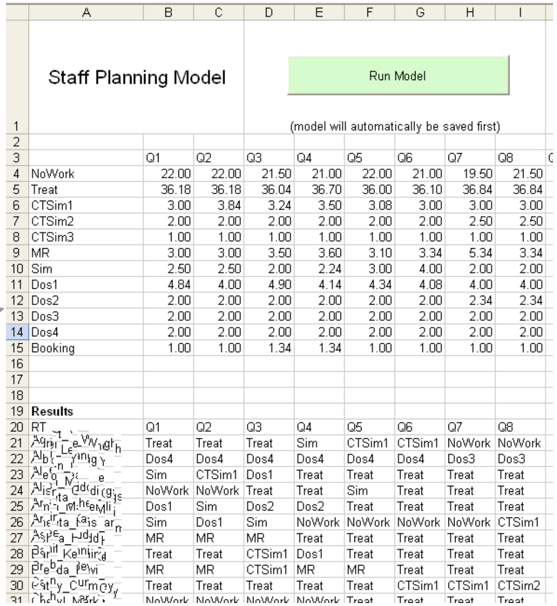
Size of Problem and Solution

- 8-quarter model:
  - Total solution time < 30 seconds
- 12-quarter model:
  - 82,406 binary variables
  - 169,827 constraints
  - 782,023 Non-zeros
  - Total solution time = 34 minutes
    - » GAMS using Cplex solver
    - » 3.00 GHz Intel Core 2 (running on single CPU of a quad chip)
    - » 16 GB ram

Model Overview







Staff Planning Model

Run Model

(model will automatically be saved first)

	A	B	C	D	E	F	G	H	I
3		Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8
4	NoWork	22.00	22.00	21.50	21.00	22.00	21.00	19.50	21.50
5	Treat	36.18	36.18	36.04	36.70	36.00	36.10	36.84	36.84
6	CTSim1	3.00	3.84	3.24	3.50	3.08	3.00	3.00	3.00
7	CTSim2	2.00	2.00	2.00	2.00	2.00	2.00	2.50	2.50
8	CTSim3	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
9	MR	3.00	3.00	3.50	3.60	3.10	3.34	5.34	3.34
10	Sim	2.50	2.50	2.00	2.24	3.00	4.00	2.00	2.00
11	Dos1	4.84	4.00	4.90	4.14	4.34	4.08	4.00	4.00
12	Dos2	2.00	2.00	2.00	2.00	2.00	2.00	2.34	2.34
13	Dos3	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
14	Dos4	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
15	Booking	1.00	1.00	1.34	1.34	1.00	1.00	1.00	1.00
16									
17									
18									
19	**Results**								
20	RT	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8
21	[illegible]	Treat	Treat	Treat	Sim	CTSim1	CTSim1	NoWork	NoWork
22	[illegible]	Dos4	Dos4	Dos4	Dos4	Dos4	Dos4	Dos3	Dos3
23	[illegible]	Sim	CTSim1	Dos1	Treat	Treat	Treat	Treat	Treat
24	[illegible]	NoWork	NoWork	Treat	Treat	Sim	Treat	Treat	Treat
25	[illegible]	Dos1	Sim	Dos2	Dos2	Treat	Treat	Treat	Treat
26	[illegible]	Sim	Dos1	Sim	NoWork	NoWork	NoWork	NoWork	CTSim1
27	[illegible]	MR	MR	MR	Treat	Treat	Treat	Treat	Treat
28	[illegible]	Treat	Treat	CTSim1	Dos1	Treat	Treat	Treat	Treat
29	[illegible]	MR	MR	CTSim1	MR	MR	Treat	Treat	Treat
30	[illegible]	Treat	Treat	Treat	Treat	Treat	CTSim1	CTSim1	CTSim2
31	[illegible]	NoWork	NoWork	NoWork	NoWork	Treat	Treat	Treat	Treat

Challenges

- Size of the model*:*
  - *more than 12 quarters takes a very long time to solve*
  - *Necessary to avoid "end effects"*
- Keeping IP formulation tight (closer to LP relaxation):
  - The addition of part-time RTs caused a couple constraints to become less tight, which increases solution time.
- Users are confused when minor changes to inputs lead to completely different plan
  - Currently testing an objective function that minimizes changes compared to last mode

Conclusions

- *Tool enables planning of RTs over next several years*
- *Can be used on a rolling horizon basis*
- *It has been used this quarter!*
- *IP balances various inputs and finds "best" solution that violates as few soft constraints as possible*
- *Current focus is on getting the tool ready for use*
- *Two papers in preparation*