Client: NorthShore University HealthSystem

NorthShore
University HealthSystem

Final Presentation
March 7th, 2017

MEET THE TEAM

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Special thanks to our client, NorthShore University HealthSystem Gastroenterology Unit, where we worked primarily with:

- Chris Cheney, Administrative Fellow
- Karen Ilag, Clinical Director for GI Services

And to our advisor, Prof. Omid Nohadani

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PROBLEM STATEMENT & PROJECT SCOPE

NorthShore needs a methodological staffing method for the nurses and lab technicians in the GI Unit

- NorthShore is experiencing cost and time inefficiencies
- Nurses' and lab techs' schedules vary with patient demand

Objective: Create a streamlined staffing model that minimizes costs

- Our linear program uses robust optimization
- We use an ellipsoidal uncertainty set to account for fluctuations in the demand and staff efficiently

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Room Utilization

By hospital, hour, day of week, month

Employee Costs

Varies by employee type

Hours of Operation

Varies by location and time of year

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THE DATA – EVANSTON PATIENT VOLUME

- Procedures are scheduled far in advance, but some seasonality occurs because of end of the year health insurance deductibles
- Highly variable patient volume patterns
- Makes stochastic model not applicable because data does not seem to follow a distribution

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THE DATA – EVANSTON ROOM USAGE

- We transformed the data from **individual patient check-in times per hour** to **hours occupied per room**
- **Justification:** limiting constraint for our staffing model will be room availability

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ROBUST OPTIMIZATION – ELLIPSOIDAL UNCERTAINTY

- Maximum demand uncertainty, ρ^2, is given by the χ^2 distribution at 90% confidence, with 6 degrees of freedom for 6 rooms
- Advantages of robust optimization:
  - Free of distributional assumptions
  - Worst case compensation
  - Applicable to any location
  - Seasonalities and differences between days of week
  - ρ^2 can be changed based on risk tolerance

This robust approach allows NorthShore to have constant schedules for the days and weeks which allows for better planning

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DATA DEPENDENT MODEL

Sets:

j: {1, 2, 3}, employee type where the numbers correspond to full-time, part-time and resource nurse, respectively

k: {1, 2, 3, 4, 5, 6}, room number

Parameters:

u_k: Uncertainty of room k, where $u_k = b_k - \mu_k$

Σ: Covariance matrix of b_k

ρ^2: Tuning parameter for uncertainty based on Chi-squared distribution

c_j: Cost of employee type j

$A_{j,k}$: Staffing efficiency matrix for each employee type j, corresponding to number of rooms used k

r_k: Room to nurse ratio for room k, scalar

b_k: Utilization (hours) of room k for each day of the week in each month for each given year, scalar

Decision Variable:

$x_{j,k}$: Staffing vector in which each row corresponds to the number of employee type recommended for each room k

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DATA DEPENDENT MODEL

Find Uncertainty Vector:

$$\max \quad u_k \rightarrow {u_k}^* \qquad \forall\, k \qquad (1)$$

$$\text{s.t} \quad {u_k}^T \Sigma^{-1} u_k \leq \rho^2 \qquad \forall\, k \qquad (2)$$

Solve Robust Linear Optimization Model:

$$\min \quad \sum_{j=1}^{3} \sum_{k=1}^{6} {c_j}^T x_{j,k} \qquad (3)$$

$$\text{s.t} \quad \sum_{j=1}^{3} A_{j,k} x_{j,k} \geq r_k (b_k + {u_k}^*) \qquad \forall\, k \qquad (4)$$

- Model assumes PT and FT staff work a certain number of hours in any given shift

We used AMPL, Julia, and R to find a solution to this model

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LIMITATIONS

Resource staff not modeled; lowest cost and allows to decouple the hospitals in order for a timely completion

The coupled model would be similar, just with an additional sum over hospitals

Weekend demand is very variable and robust solution would be too conservative, hence we excluded it from consideration

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RESULTS

- Resource staff can be utilized to compensate for inconsistencies in staffing throughout any given week by replacing full-time and part-time nurses, where needed
- These staffing complement ratios would translate to other hospital locations

Our Staffing Recommendation for Nurses in Evanston (FT, PT)

	Mon	Tues	Wed	Thurs	Fri
January	(5, 9)	(6, 3)	(4, 4)	(7, 3)	(5, 3)
February	(7, 3)	(6, 2)	(5, 3)	(7, 3)	(5, 4)
March	(10, 0)	(7, 1)	(5, 3)	(7, 3)	(7, 2)
April	(6, 4)	(9, 2)	(5, 3)	(6, 3)	(5, 3)
May	(4, 4)	(9, 1)	(6, 2)	(5, 4)	(7, 1)
June	(9, 1)	(8, 2)	(6, 2)	(6, 2)	(6, 3)
July	(9, 2)	(9, 2)	(6, 4)	(8, 2)	(6, 2)
August	(6, 3)	(6, 5)	(5, 3)	(6, 3)	(6, 2)
September	(7, 3)	(8, 2)	(6, 2)	(8, 3)	(7, 2)
October	(10, 1)	(6, 4)	(5, 3)	(7, 3)	(6, 2)
November	(10, 0)	(9, 1)	(6, 2)	(7, 2)	(5, 3)
December	(7, 3)	(7, 3)	(5, 3)	(6, 3)	(5, 3)

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NEXT STEPS

Incorporate resource staff into robust linear optimization model

Perform analysis for all locations with with their own demands and constraints

Accommodate for the different complexities of weekend demand

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THANK YOU!

ANY QUESTIONS?

REFERENCES

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[4] Schouten, Pieter. "Better Patient Forecasts and Schedule Optimization Improve Patient Care and Curb Staffing Costs." Becker's Hospital Review.

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APPENDIX

PATIENT VOLUME

- Patient volume is larger in the beginning of the week
- Possible cause includes proximity to weekend

- Patient volume is larger in morning
- Possible cause includes eating restrictions before surgery

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PATIENT VOLUME

- Small increase at end of year due to holiday scheduling and insurance deductibles
- Generally stationary demand
- Potential correlation of demand at different locations

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GI PROCEDURES

Breakdown of Procedure Type

- As expected, colonoscopies are the majority of procedure types
- "Other" accounts for 50 different procedure types

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GI PROCEDURES

Histogram of Procedure Duration Times

Type of Procedure	Avg. Procedure Length (min)
Colonoscopy	23.2
EGD	13.7
EGD & Colon.	30.0
Enteroscopy	43.5
ERCP	39.7
Sigmoidoscopy	15.0

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EMPLOYEE INFO

	Without Fringe, hourly			With Fringe, hourly		
Job Title	Min	Mid	Max	Min	Mid	Max
GI Technologist	--	--	--	$18.23	$23.32	$28.41
Staff Nurse	--	--	--	$34.17	$44.70	$55.25
Staff Nurse Tier 2 Resource	$25.19	$32.98	$40.77	--	--	--

NorthShore location:	Evanston	Glenbrook	Highland Park	Skokie	Vernon Hills	HP Medical Group
# of FTEs on staff:	9.3 staff RNs. 4.8 GI techs	9.4 staff RNs. 6.0 GI techs	8.8 staff RNs. 6.0 GI techs	8.0 staff RNs. 5.0 GI techs	1.8 staff RNs. 1.5 GI techs	3.0 staff RNs. 3.0 GI techs

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