Centre intégré
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du Centre-Ouest-
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Québec

An Operational Research Perspective On Improving Healthcare Delivery In Quebec

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The Operational Research Approach

- In Britain during the 1930s, there was a growing sense that war with Germany was imminent
- To prepare for it, Britain's military assembled interdisciplinary teams consisting of military personnel, scientists, physiologists, physicists and mathematicians, to understand and then improve military operations such as the use of radar [Cunningham 1984] [Lindsey 1995].
- The success of these teams led to the establishment in each of Britain's military services of operational research groups, so named because of the research these groups performed on military operations.
- Common to these efforts:
  - Was the need to understand those operations from multiple perspectives
  - Then use of analysis to optimize performance
  - The involvement of individuals at all levels

The Presentation

- **Disclosure**
- System wide challenges facing health care delivery
- Bill 10
- Analytics
- Information Systems
- Organizational change
- Making it all work
- My role

Disclosure

- While this presentation contains new ideas, it also contains ideas that have been presented or discussed by other individuals
- The views and opinions expressed in this presentation are not intended to reflect the views of the Integrated Health and Social Services University Network for West-Central Montreal
- What is most important about this presentation is that it presents, in a unified manner, thoughts on improving healthcare delivery in Quebec

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System Wide Challenges Facing Health Care Delivery

- The variability and lack of predictability in the day to day need for healthcare
  - Queueing effects due to variability
  - Difficulty in managing queueing effects due to lack of predictability

System Wide Challenges Facing Health Care Delivery

- Health care delivery is not always well coordinated:
  - ED physician staffing
  - Patients waiting for a PICC line to be inserted to leave hospital
  - Patients waiting for a bed in rehabilitation facility to leave hospital

System Wide Challenges Facing Health Care Delivery

- Many healthcare delivery processes are poorly designed or implemented:
  - Many processes in all industries often started off well designed but as volumes grew . . .[Hammer 1990]
  - Historically medical staff were not trained in process design

System Wide Challenges Facing Health Care Delivery

- Redundancy of information collection

- Every time a patient has a new type of need or changes his/her status

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Bill 10

- Passed in late 2014 Bill 10 mandated that:
  - Most healthcare institutions in Quebec be amalgamated into CISSSs
  - CISSSs be responsible for ensuring that the health and social service needs of the people in their territory were addressed
    - Directly by the CISSS
    - Via corridors to/with other CISSSs

- Management perspective – CISSS gives management the ability to specify:
  - Which services
  - Where within the CISSS
  - When
  - How much

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Analytics

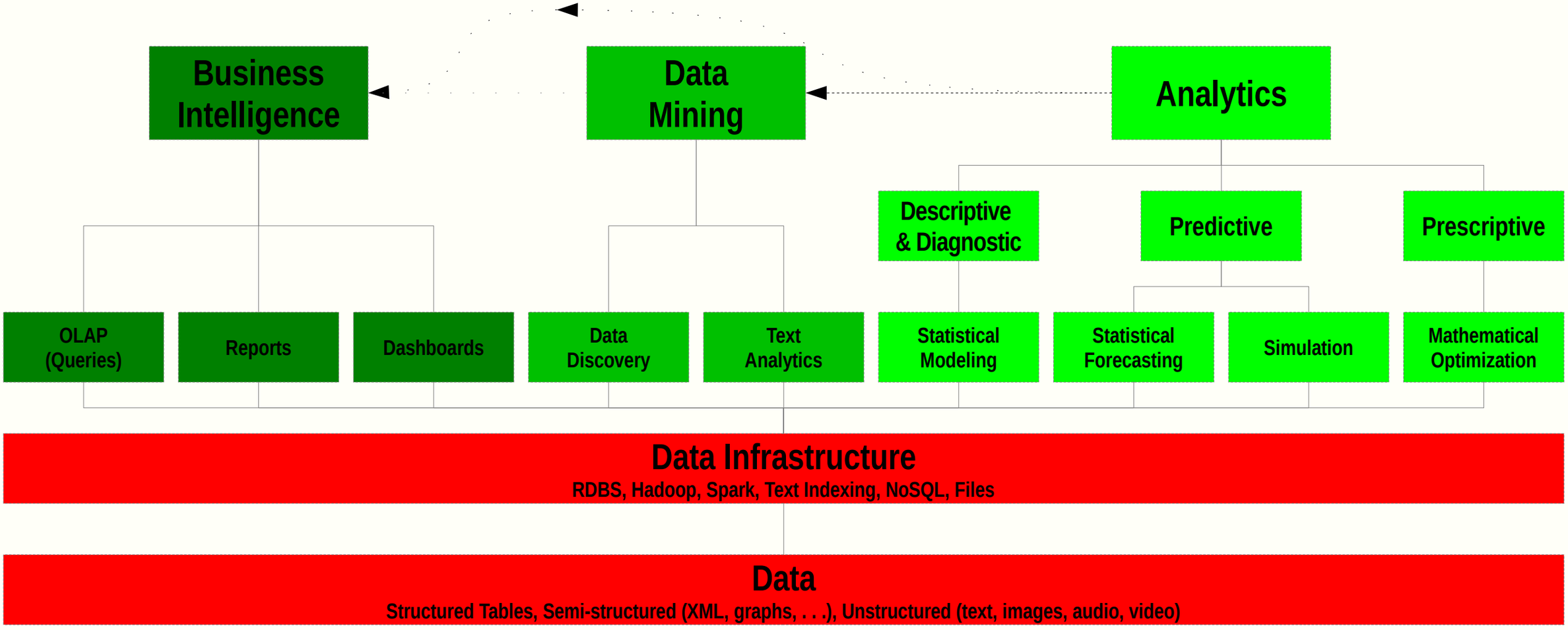
- One of the key components of the Operational Research approach is the use of analysis (currently called analytics) to optimize operations

- So

  - What is analytics?

  - How can analytics be used to help address our healthcare delivery challenges?

Business Intelligence Versus Data Mining Versus Analytics



Modified from https://rapidminer.com/resource/introduction-advanced-analytics/

Descriptive Analytics – Measurement And Modelling

- Measurement - "I often say that when you can measure what you are speaking about, and express it in numbers, you know something about it; but when you cannot measure it, when you cannot express it in numbers, your knowledge is of a meagre and unsatisfactory kind; it may be the beginning of knowledge, but you have scarcely in your thoughts advanced to the state of Science, whatever the matter may be."

  Lord Kelvin, 1883

- Modelling - Identifying the relationships (if any) between measurable quantities

Descriptive Analytics – Suggested Usage

- Healthcare outcomes
- Provided health care
- The resources needed to provide each unit of each type of health care
- The resources used to provide each type of health care
- The need for healthcare at an individual level (along with relevant demographic information such as gender age, occupation)
- Prescribed treatment and care pathways at an individual level
- Patient compliance with prescribed treatment and care pathways

Diagnostic Analytics - Suggested Usage

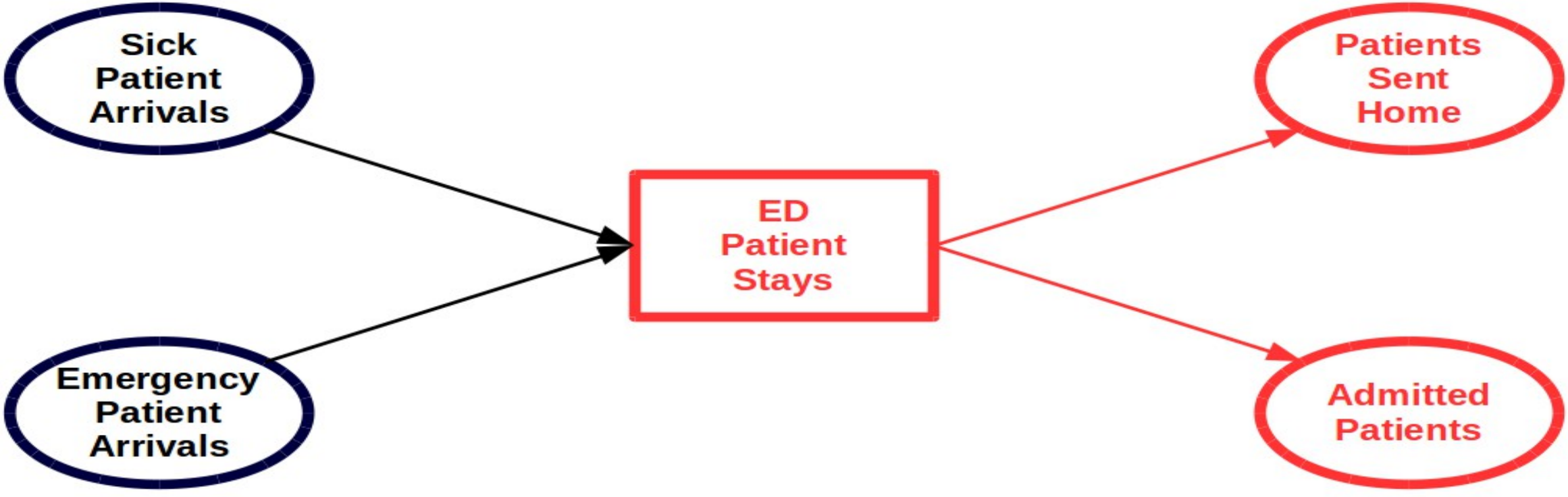
- Using the measurements/models just discussed it should be possible to:
  - Identify quality issues such as diagnoses for which particular healthcare providers are not obtaining good outcomes
  - Compare resources needed to those consumed for current outcomes
  - Identify diagnosis and treatment types with poor patient compliance
  - Identify successful and cost effective integrated care pathways

Predictive Analytics - Predicting Relative Likelihoods Of Future Outcomes

- Tools
  - Statistical forecasting tools
  - Monte Carlo Simulation
    - System dynamics
    - Discrete Event Simulation
    - Agent based

Predictive Analytics

- Statistical Forecasting Tools
  - Quite helpful for predicting individual phenomenon
  - Harder to use to see effect of joint phenomenon



Predictive Analytics - Monte Carlo Simulation

"Simulation is the process of designing a model of a real system and conducting experiments with this model for the purpose of either understanding the behavior of the system and/or evaluating various strategies for the operation of the system."

Introduction to Simulation Using SIMAN (2nd Edition)

Predictive Analytics - A Simulation Model

Predictive Analytics - Monte Carlo Simulation

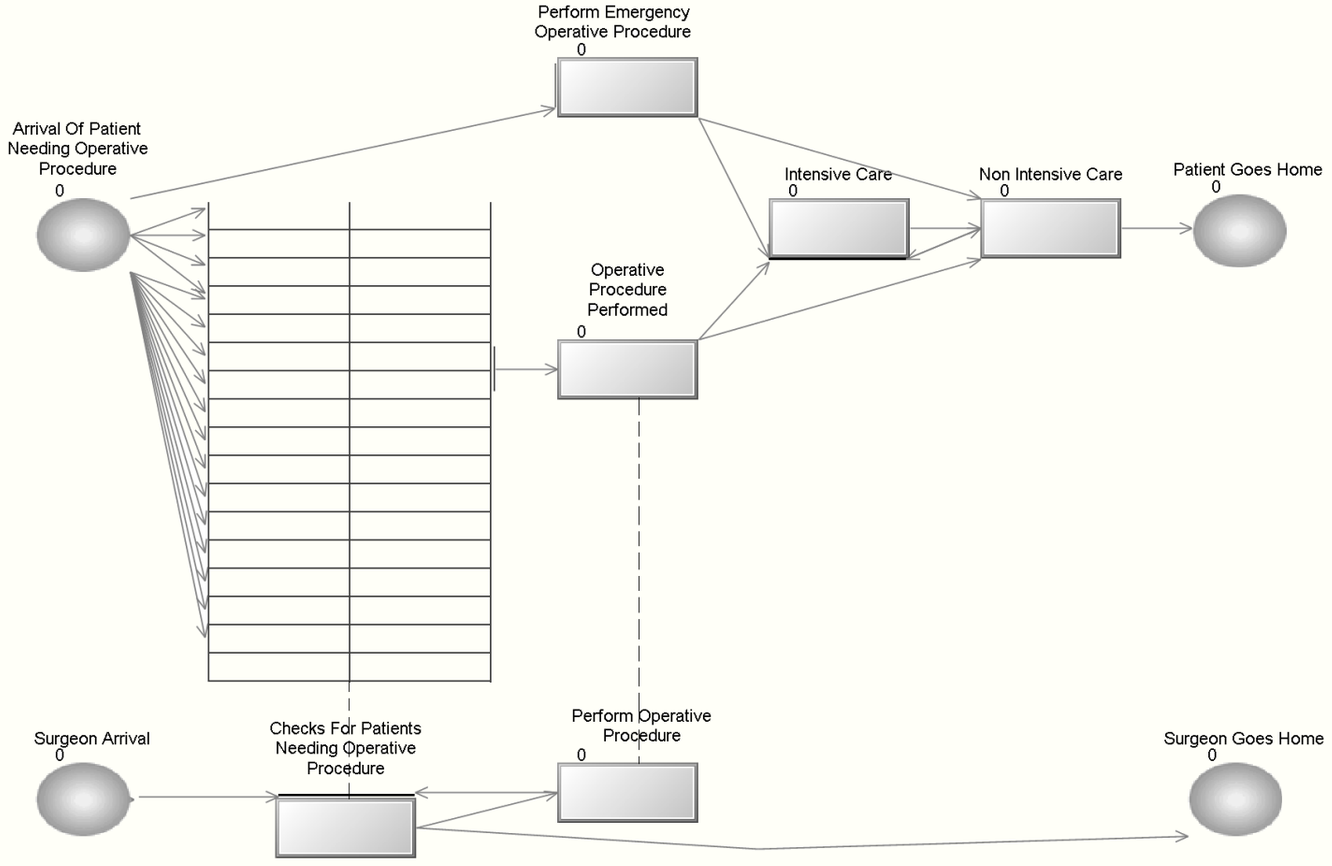
- *Build a model of a process or a system (usually on a computer to facilitate running the model many times)*
- *Run the model many times (usually on a computer)*
- *Each time use a different set of randomly selected values drawn from the family of values that underlies the real process*
- *Make sure that the average statistics match those in real life*
- *Modify the model to reflect proposed changes to the process or system*
- *Hypothesize the effect of the changes*
- *Measure the average statistics of the revised process*
- *Test the hypothesis with the statistics of the original process and the revised process*

The methodology underlying this approach, the Monte Carlo Method, was named by John von Neumann, Stanislaw Ulam and Nicholas Metropolis after the casino where Stanislaw's uncle frequently gambled.

Predictive Analytics - Example

- Using Simulation To Determine The Need For ICU Beds For Surgical Patients At The Sir Mortimer B. Davis Jewish General Hospital, Presentation at the Central Surgical Association, Philip Troy and Lawrence Rosenberg.
  - At the time, there were frequent cancellations of operative procedures requiring immediate ICU stays
  - In particular, late in 2007 there was an extended period during which a very large number of cardiac surgeries needed to be postponed due to a lack of ICU beds
  - As a result, Dr. Rosenberg wished to determine the number of beds that would be needed if there were a surgery only ICU

Predictive Analytics - Example



Predictive Analytics - Example

- Facilitates computation of statistics

Functional ICU Beds	Mean Wait (Days)	Mean Cancelled Blocks
6	535	473
7	411	404
8	304	336
9	207	262
10	131	195
11	79	136
12	43	88
13	24	50
14	13	24
15	9	12
16	7	5
17	7	2

Predictive Analytics - Tactical Usage

- Build a predictive simulation model of a part of (or all of) a health care delivery system:
  - An ED
  - An IPU
  - A hospital's peri-operative processes
  - A (complex) clinic
- Verify the model
- Validate the model
- Use the model to estimate:
  - The cost of health care delivery to specific standards (now/in the future)
  - Health care delivery performance metrics for suggested alternatives

Predictive Analytics - Operational Usage

- Typically for shorter term analysis, for example:
  - For the hospital's peri-operative processes:
    - Use current ICU and surgical bed statistics
    - Identify potential bottlenecks/issues that would be caused by a particular OR schedule for a particular day before finalizing that schedule

Prescriptive Analytics

- Use of algorithms/heuristics to:
  - Identify alternatives
  - Evaluate the performance of alternatives
  - Provide decision support for risky/high impact decisions
    - suggest (several of) the best alternatives for management
  - Make decisions for routine/low risk/low impact decisions
- Can be used for strategic, tactical and operational purposes
- Generally requires a mathematical statement of:
  - Goals
  - Constraints

Prescriptive Analytics - A Simple Example

- The budget for hot dogs and soda for a holiday party at the CIUSSS is $200
- Hot dogs each cost $2
- Sodas each cost $1
- There will be 30 people at the party
- There must be at least two hot dogs and one soda for each person
- The average satisfaction of people for hot dogs is 3
- The average satisfaction of people for sodas is 1

- How many hot dogs and sodas should be bought to maximize total satisfaction of the party goers while staying within the budget?

Prescriptive Analytics - A Simple Example

- We can state (or model) this problem mathematically with:
  - An objective function
  - Constraints

- Maximize 3 * Hot Dogs + 1 * Sodas
- Subject to:
  - HotDogs $\geq$ 60
  - Sodas $\geq$ 30
  - 4 * Hot Dogs + 2 * Sodas $\leq$ 200

- Should we wish we can readily add other constraints and variables

Prescriptive Analytics - A Simple Example

- We can readily solve this problem using Linear Programming software (found in Excel for free for small problems and elsewhere for a fee for larger problems)
  - 35 Hot Dogs
  - 30 Sodas

- We can also readily determine the sensitivity of the solution to the parameters of the problem:
  - The budget
  - The minimum number of hot dogs and sodas
  - The satisfaction of eating a hot dog and drinking a soda

Prescriptive Analytics

- To perform prescriptive analytics we need goals and constraints

- Typical goals:
  - For businesses – maximize profits
  - For public health care:
    - Minimize costs
    - Maximize health care value

- Typical constraints:
  - Budget
  - Minimum and/or maximum resource usage
  - Minimum performance

Prescriptive Analytics - Health Care Value

- When using prescriptive analytics for health care delivery in a public system like that of Quebec, choosing an appropriate goal is important
  - We are not generally interested in profit
  - We would however like to maximize the value generated by the health care system

    "In health care, value is defined as the patient health outcomes achieved per dollar spent.

    Michael Porter, Supplementary Appendix 1 to Porter M.E., What is value in health care?, N Engl J Med 2010; 363:2477-81.

- Mathematically we often maximize value by setting our goal to maximize outcomes after adding a budget constraint

Prescriptive Analytics

- Strategic applications
  - Services to be provided to align institutions in network to maximize outcomes related to their foundations' goals
  - Corridor arrangements with other networks

Prescriptive Analytics

- Tactical applications:
  - Which services
  - Where within the CISSS
  - When
  - How much
  - Scheduling

Prescriptive Analytics

- Operational applications:
  - Staff scheduling
  - Patient scheduling
  - Resource assignments

The Potential Of Analytics For Improving Health Care Delivery

- The variability and lack of predictability in the day to day need for healthcare
  - Queueing effects due to variability
  - Difficulty in managing queueing effects due to lack of predictability

- To address this challenge:
  - We can apply insights from queueing theory to propose process changes
    - Pooling of services
    - Adjusting service capacities
    - Non-admission to queues
  - We can use predictive analytics to evaluate proposed process changes

The Potential Of Analytics For Improving Health Care Delivery

- Insights from queueing theory relevant to addressing variability and lack of predictability in the day to day need for healthcare . . .
  - Pooling of services

Average Arrival Rate (Equally	5 Individual Unpooled Queues		1 Pooled Queue With 5 Servers	
Distributed To Non-Pooled Queues)	Average People Waiting	Average Wait Per Person	Average People Waiting	Average Wait Per Person
2.5000	2.5	1.0	0.1	0.1
3.0000	4.5	1.5	0.4	0.1
3.5000	8.2	2.3	0.9	0.3
4.0000	16.0	4.0	2.2	0.6
4.5000	40.5	9.0	6.9	1.5
4.9500	490.1	99.0	96.5	19.5
4.9950	4,990.0	999.0	996.5	199.5
4.9995	49,990.0	9,999.0	9996.5	1999.5

  - Adjusting service capacities
  - Non-admission to queues

The Potential Of Analytics For Improving Health Care Delivery

- Health care delivery is not always well coordinated:
  - ED physician staffing
  - Patients waiting for a PICC line to be inserted to leave hospital
  - Patients waiting for a bed in rehabilitation facility to leave hospital

- To address this type of challenge:
  - We can use prescriptive analytics to propose process changes such as determining good times to change resources assigned to specific tasks
  - We can use predictive analytics to evaluate proposed process changes

The Potential Of Analytics For Improving Health Care Delivery

- Many healthcare delivery processes are poorly designed or implemented:
  - Many processes started off well designed but as volumes grew . . .
  - Historically medical staff were not trained in process design

- To address this type of challenge:
  - We can use prescriptive analytics in conjunction with lean to propose process changes
  - We can use predictive analytics to evaluate proposed process changes

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Information Systems - Potential

- Improving measurement
- Improving coordination
- Electronic referral system
- Province (or nationwide) pharmacy system
- Province wide medical records (that are analyzable)
- Decision support systems
- Patient follow up/adherence management

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Organizational Change - Redesign

- Should we be designing a different organizational structure?

Organizational Change - Realignment Of Providers And Users

- Kaplan & Norton [Kaplan 1996]
  - Mobil quickly changed itself from being the worst of the major oil corporations to one of the best
  - The key to that transformation was
    - The use of balanced scorecards aligned to the corporation's strategy
    - A reward structure for individuals at each level

- For Quebec there appears to be a major need for realignment of:
  - Management and staff
  - Physicians
  - Clients

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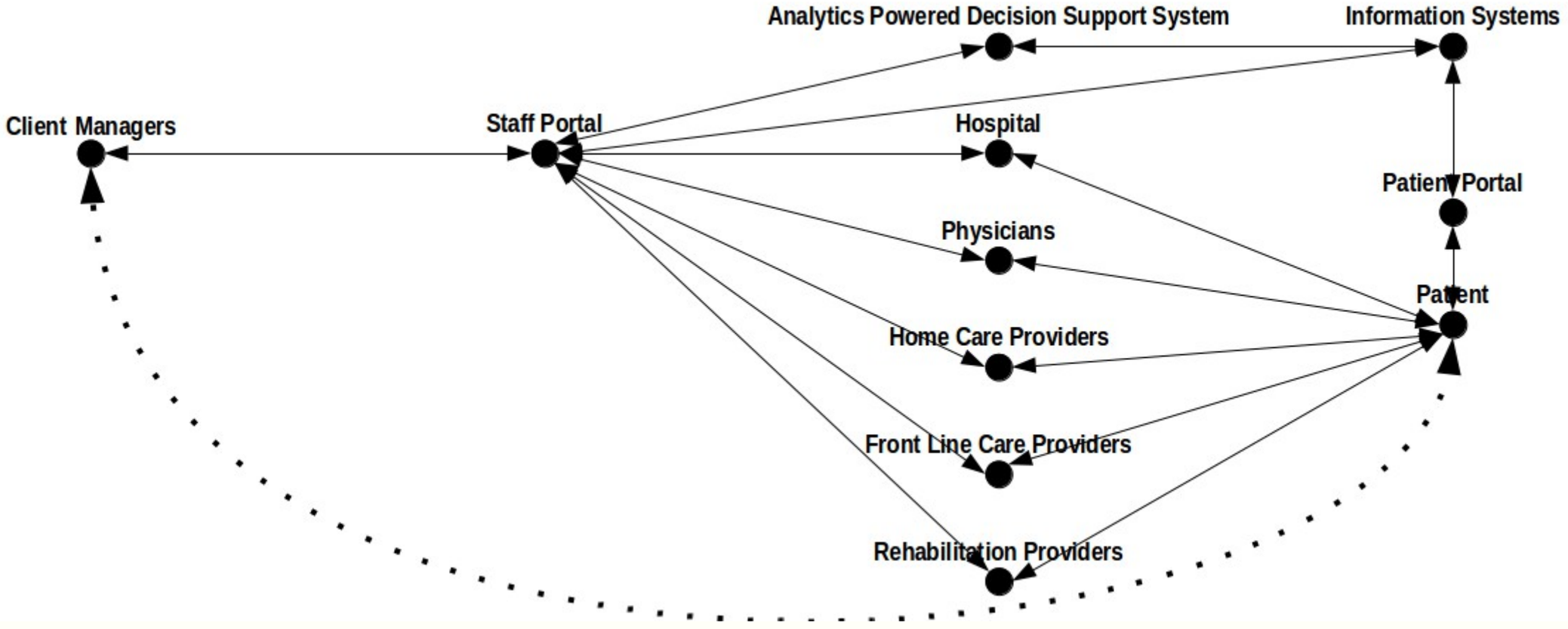
Making It All Work

- Clearly integrating analytics, information systems, organizational change is critical



Making It All Work

- But the other essential part of the Operational Research approach is involving individuals at all levels of the healthcare delivery system

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My Background

- B.Sc. Engineering Science, The Pennsylvania State University
- M.Sc. Quantitative Business Analysis, The Pennsylvania State University
- Ph.D. Operations Research, Yale University
- Software developer
- University lecturer and professor
- Simulation modeller
- Consultant

My Role

- Senior Analytics Advisor
- In the department of quality, evaluation, performance, ethics and archives
- Responsibilities include:
  - Advising management on the potential use of analytics
  - Building awareness of how analytics can be used
    - Analytics Lecture Series
    - Analytics courses
  - Acting as a resource to other analysts (via the Analytics Round Table)
  - Working on projects where analytics can positively impact health care delivery

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Questions