Centre for Health Care Management
THE UNIVERSITY OF BRITISH COLUMBIA

Using Operations Research to Improve Health Care Delivery

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What is Operations Research?

- A systematic way of thinking about management and decision making.
- OR helps managers make tough decisions, solve critical operating problems, and shape important policy.
- OR use quantitative models to guide the allocation of scarce resources and tradeoff risk with gain.
- OR methods address both long term planning and day to day operations challenges.

What is Operations Research?

- A set of mathematical tools to quantify, represent and improve system performance.
  - **Operations research is more than simulation!**
  - Methods include linear programming, discrete optimization, queuing models, forecasting and dynamic programming
- To implement operations research analyses, OR professionals create computer based decision-support systems with the following goals:
  - Optimize system performance
  - Enable “What if” analyses
- Operations researchers are mathematical efficiency experts
- Operations research is “The Science of Better” – *Informs*
- Its origins date to the 1940’s

How is OR used in health care

- Improving system efficiency
  - Optimally scheduling staff and procedures
  - Identifying and removing bottlenecks
- Planning system changes
  - Capital expenditures
  - Workforce planning
- Medical decision making
  - Sequencing therapies
  - When to start or change therapy
- Public health
  - Vaccine supply chain planning and design
  - Pandemic response strategies
- Complex process optimization
  - Radiotherapy planning

Selected CHCM OR Projects

- Nurse and radio therapist workforce planning
- Long term care facility capacity planning
- Optimizing patient scheduling for diagnostic imaging
- Cancer radiology demand forecasting, efficient resource utilization and treatment timing
- Medical decision making and drug innovation
- Optimizing robotic surgery
- Surgical scheduling and patient flow
- Bed utilization management
- Detecting health care worker injury patterns
- Enhancing porter services

Wait Times

Challenges in measuring wait times

- **Patients are not homogeneous**
  - Different *priority (or urgency) classes* of patients face (and should face) different wait times.
- **Wait times, as currently measured, do not tell the whole story**.
  - Wait Time usually equals the length of time between when request for service and service delivery.
  - Ignores upstream process steps and delays.
  - Data often not linked across system components such as primary care, specialists, surgeons and hospitals

Challenges in measuring wait times

- **Averages do not tell the whole story**
  - Wait times *vary* between patients, over time and between sites.
  - Performance measures must account for variability
  - Wait time distributions are skewed and may be censored
- **Reliable and complete wait time data is often not available**
  - Patient records often not linked across interfaces
  - Variability and performance cannot be determined reliability
  - Data is often censored
    - Especially challenging when stays are long and rates are changing
- **Recommended Metrics**
  - "Proportion of patients of a specific priority class who receive the service within a specific clinically desirable time"
  - These provide meaningful guarantees to decision makers and system users.
  - OR optimization models have difficulty with such metrics.
    - This is one reason simulation models are widely used.

Levers for reducing wait times

- Add capacity
- Use current capacity better
  - Schedule inflows where possible
  - Shorten lengths of stay
  - Match shift schedules with demand patterns
- Use flexible (surge) capacity
- Manage demand

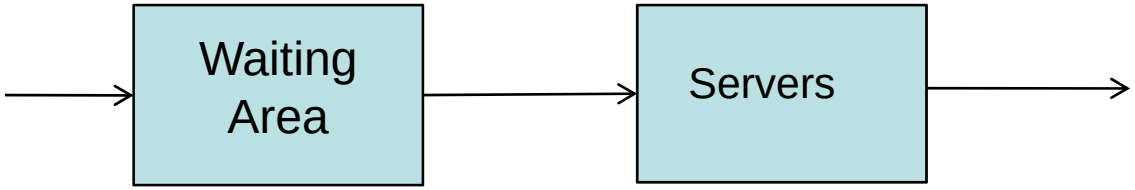
Matching Capacity and Demand

Matching Capacity with Demand

- To address excessive wait times and to use resources well, many managers strive to match capacity with demand.
- What does this mean?
- Is this desirable?
- Queuing theory provides insights

Queuing 101

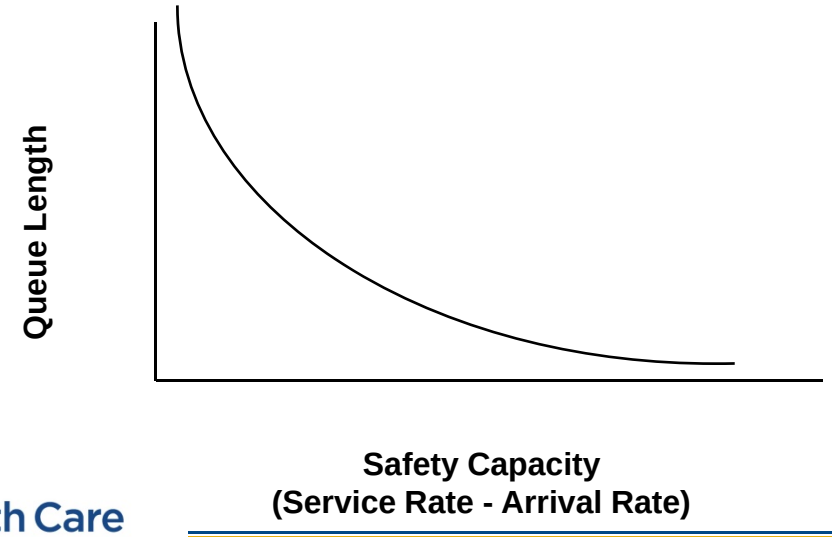
- A simple queue



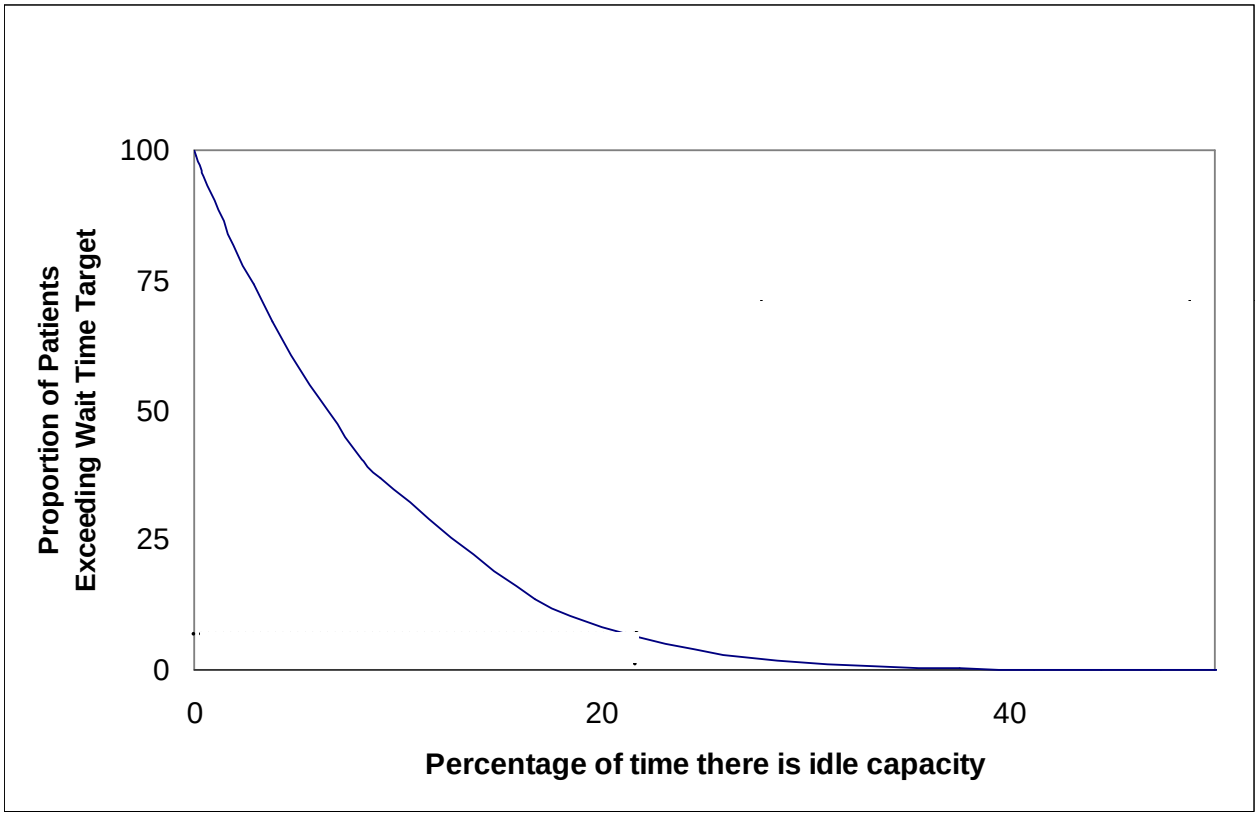
- There may be no waiting room! (When?)
- How do we describe a queue
  - Random Arrival Times (Rates)
  - Random Service Times (Rates)
- What can we estimate from queuing theory?
  - Queue lengths
  - Wait times
  - Utilization

Matching Capacity with Demand

- If average capacity matches average demand and *no variability* is present a system works smoothly.
- Otherwise queuing theory says there will be long wait times.



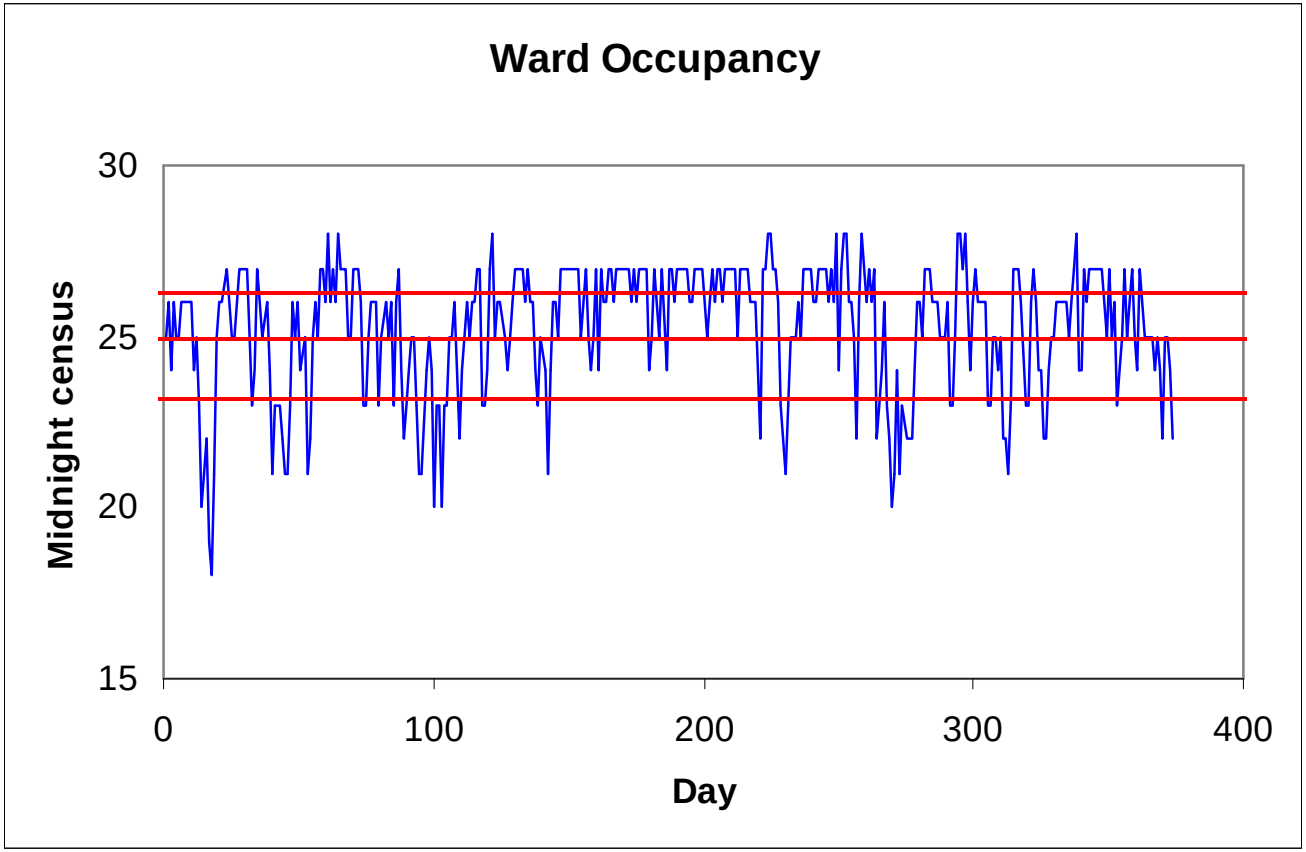
Idle Capacity And Wait Time Targets



How Much Capacity is Needed?

- Operations Research models tradeoff base cost and overtime costs to determine optimal capacity levels
- Operations Research provides rules for when and how to use *surge capacity*

How Much Capacity is Needed? Example



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Scheduling Diagnostic Imaging

Jonathan Patrick

Martin Puterman

Sauder School of Business

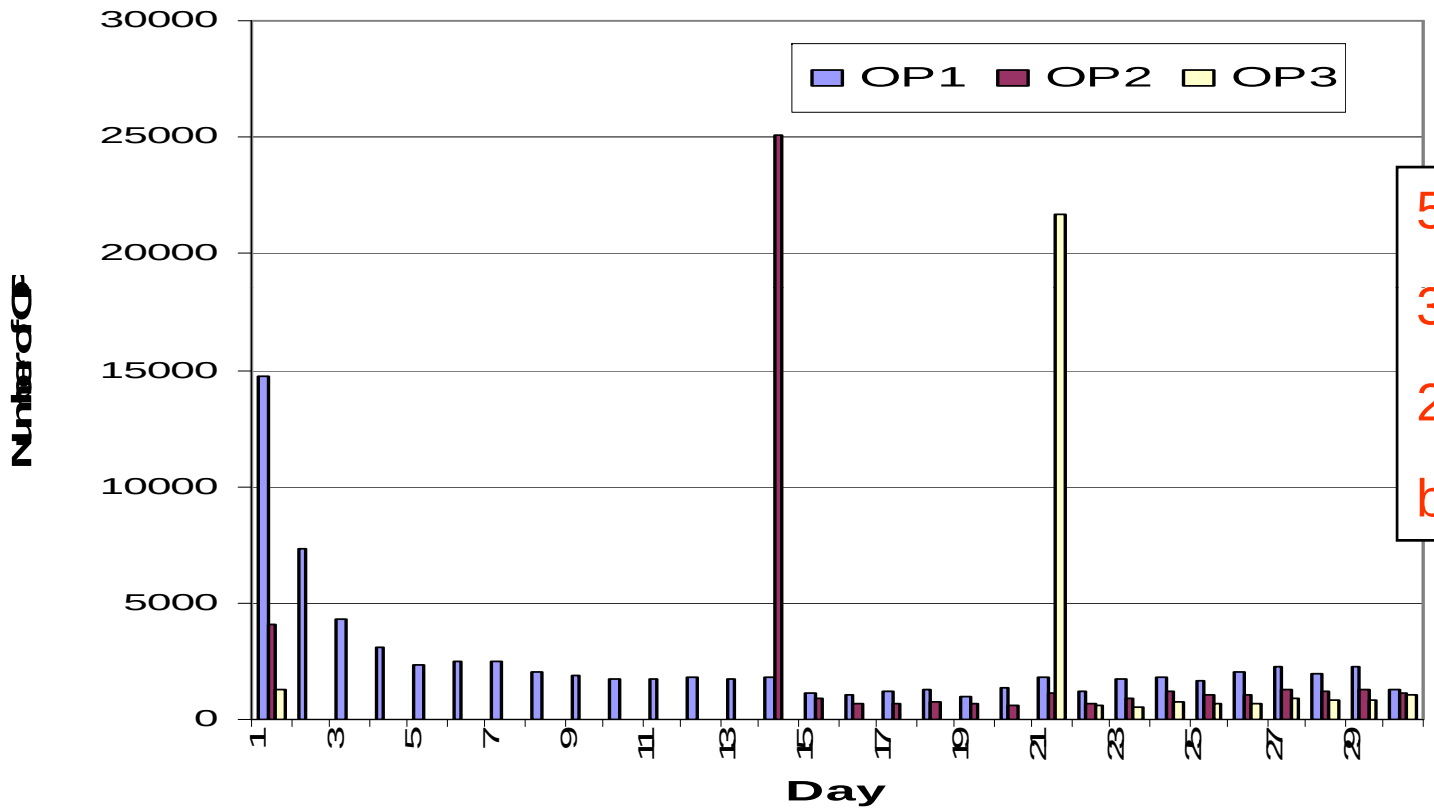
A Typical Scheduling Problem

- Demand for a diagnostic resource comes from three sources:
  - Emergency – booked immediately
  - Inpatient – booked within 24 hours
  - Outpatient – booked days or weeks in advance
    - OP demand is classified by priorities by radiologists
- Capacity is limited!
- This study focuses on scheduling outpatient demand
- **Challenge**: Must book low priority classes for specific future days without knowing the amount of future higher priority demand.
- **Goal:** Produce a good (optimal) plan that a booking clerk can use to schedule diagnostic procedures.

Optimal Policy

- Book highest priority patients at earliest time possible prior to target date; if no space available use overtime
- Book priority 2 tomorrow, at or before target, or if no space is available use overtime
- Book priority 3 tomorrow, at or before target, or if no space is available use overtime
- …

Waiting Time “Current” Policy



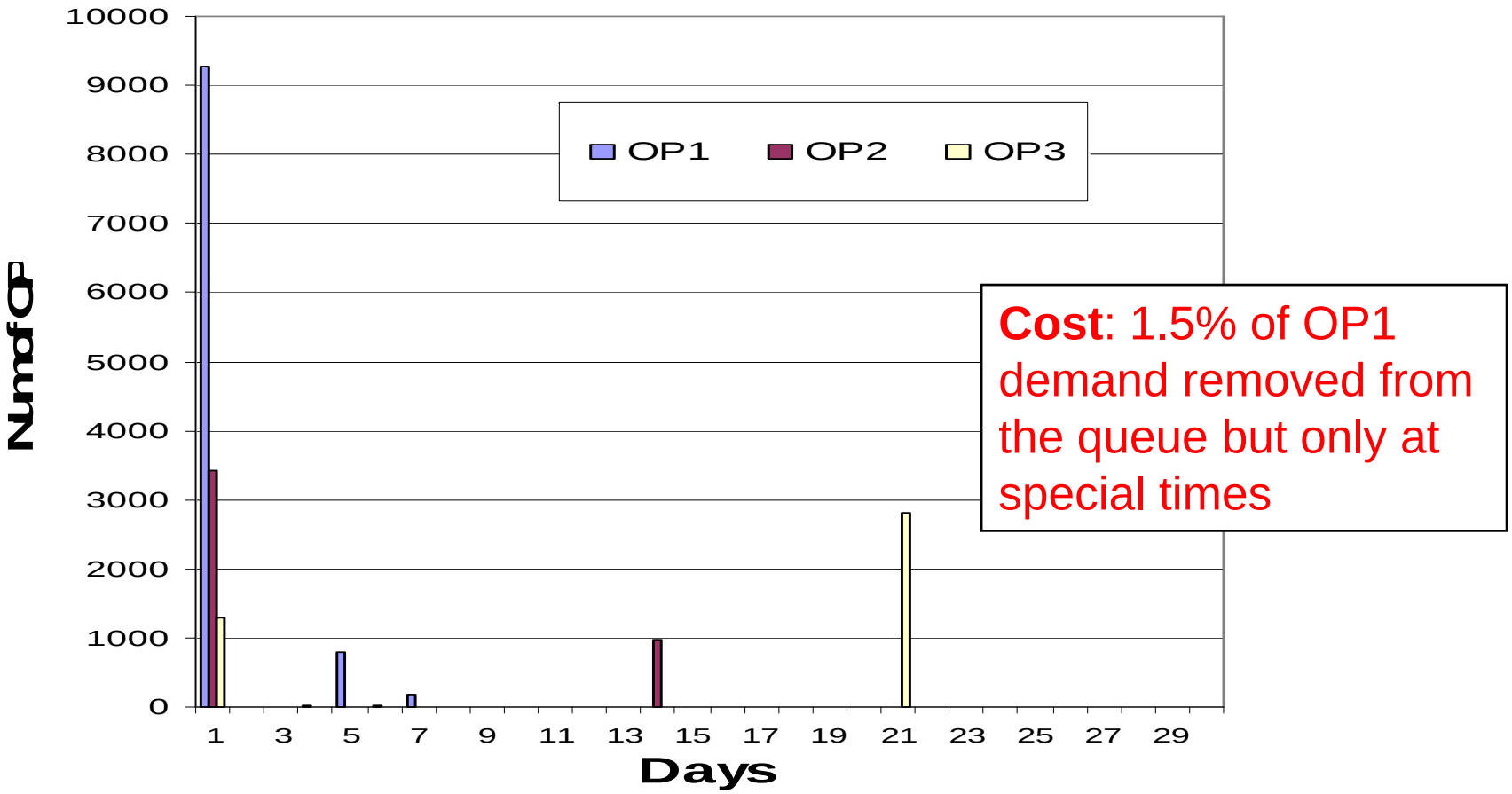
53% of OP1,

36% of OP2,

25% of OP3

booked late!

Case Study: Simulated Wait Times Under Optimal Policy



Cost: 1.5% of OP1 demand removed from the queue but only at special times

Policy Insights

- In a system where demand is close to capacity, the judicious use of a small amount of overtime coupled with intelligent patient scheduling can meet wait time targets
  - Overtime gives the resource manager the ability to deal with spikes in demand
  - Without this ability, once the system is behind, it can't catch up
  - This reduces the need for excess base capacity
- Booking demand later and later merely compounds the problem
  - Best to address the problem directly through the judicious use of overtime

Long Term Care Capacity Planning

Based on work of

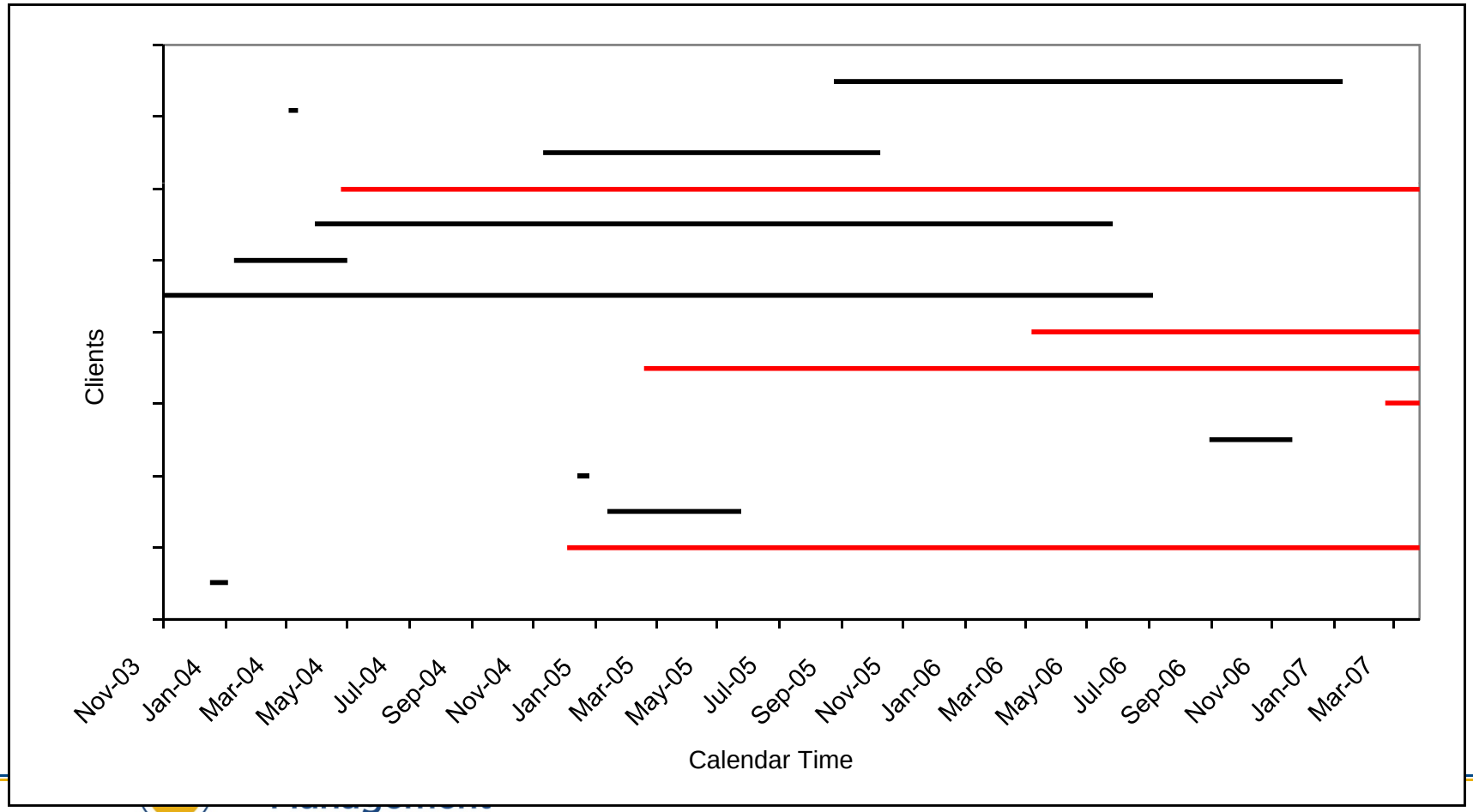
Matthew Nelson, Derek Atkins and Martin L. Puterman – Sauder School of Business

Steve Atkinson - VIHA

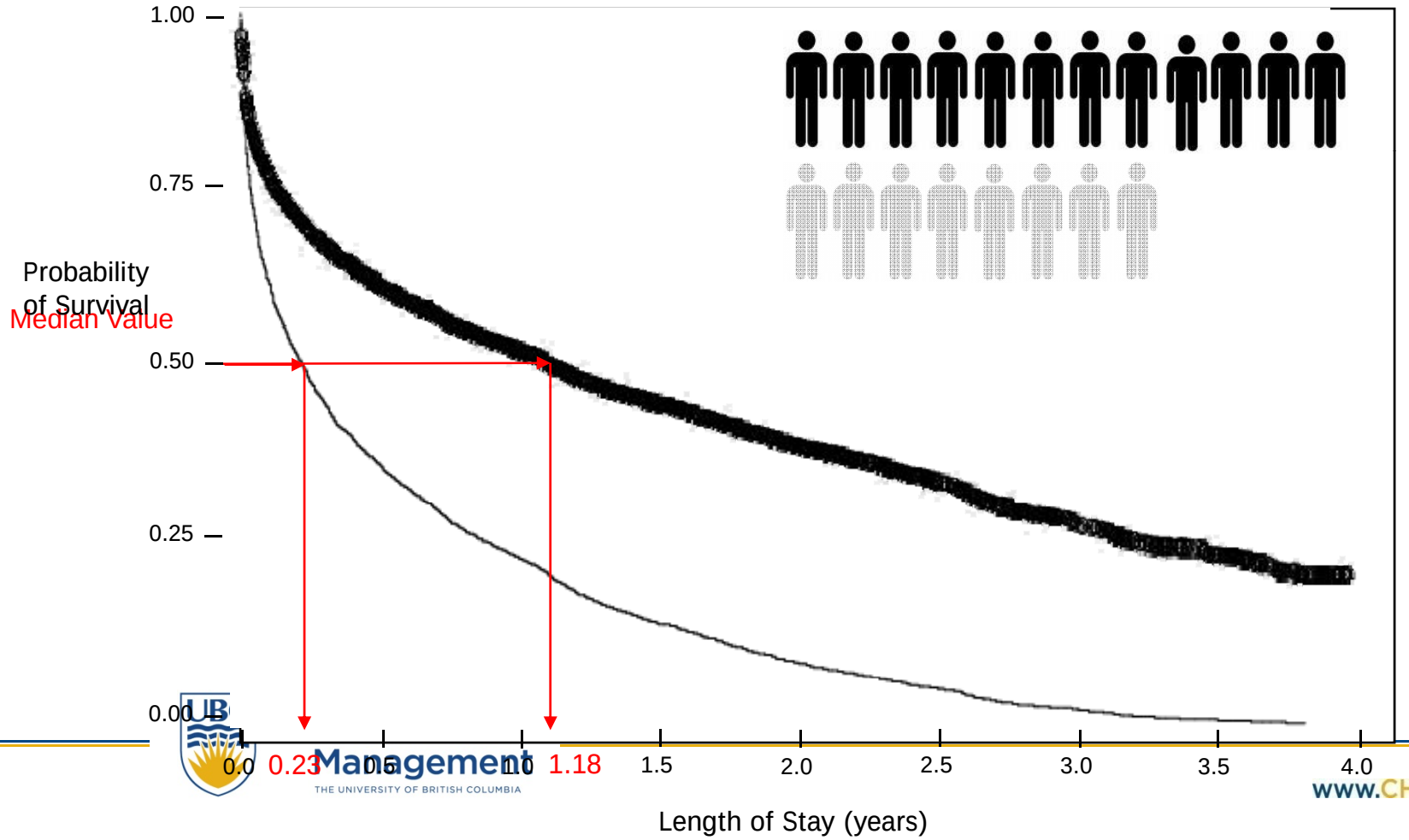
Project Overview

- Develop a model to support long term care capacity planning decisions
  - Model will forecast the annual bed requirements sub-region through 2020
  - Will allow sensitivity and “What if?” analysis
- This is a fundamental planning problem faced by all health system planners
- Standard approach – Ratio based planning
  - Ratios of population 75 and older
  - Usually between 75-90 per 1000 75 or older
- Our approach – *Service criteria based planning*
  - Methods -simulation model, survival analysis, goal seeking
  - Determine capacity levels to meet a standard such as 85% of clients wait less than 30 days

Sample Data


Clients
Nov-03
Jan-04
Mar-04
May-04
Jul-04
Sep-04
Nov-04
Jan-05
Mar-05
May-05
Jul-05
Sep-05
Nov-05
Jan-06
Mar-06
May-06
Jul-06
Sep-06
Nov-06
Jan-07
Mar-07
Calendar Time

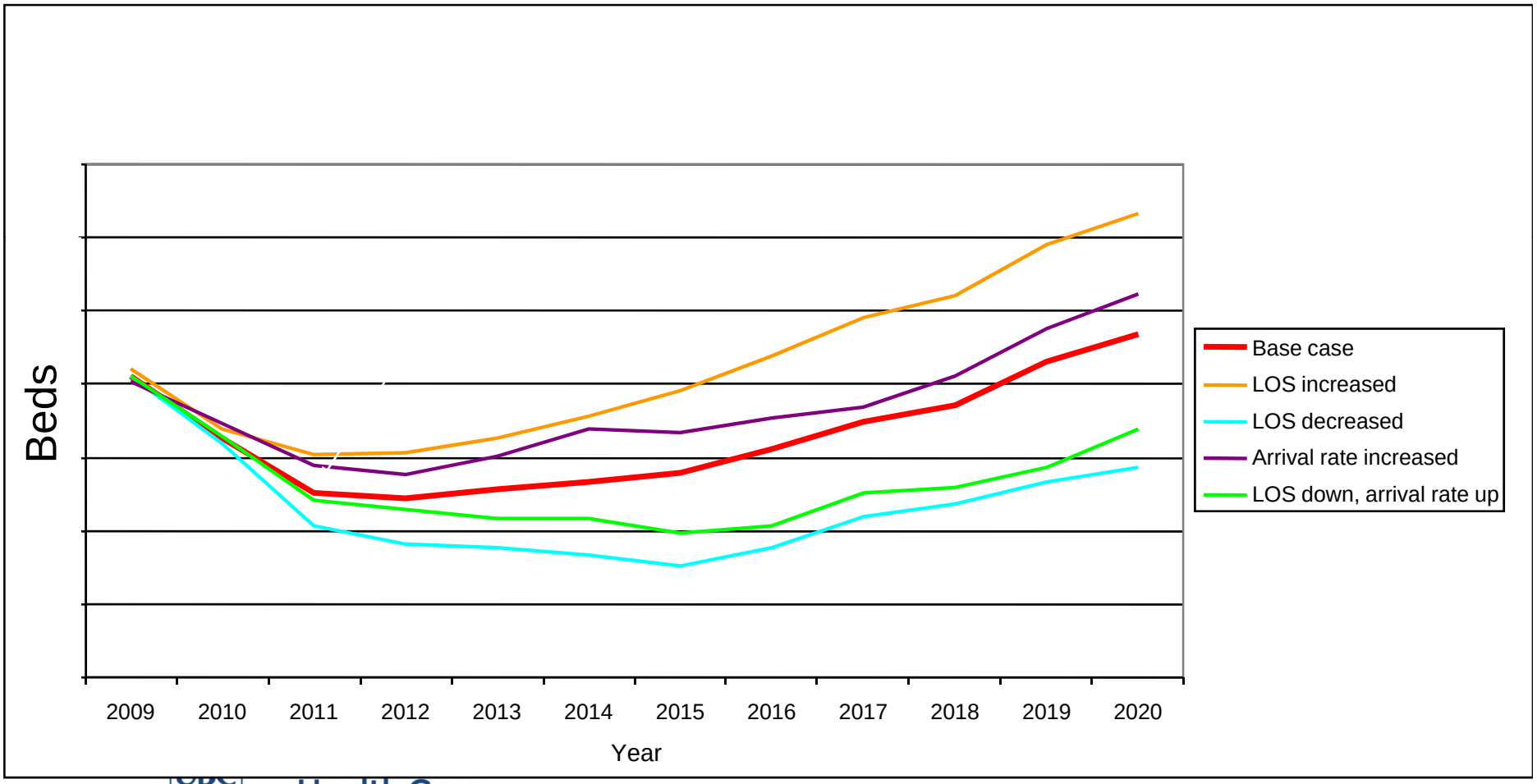
Why does this matter?



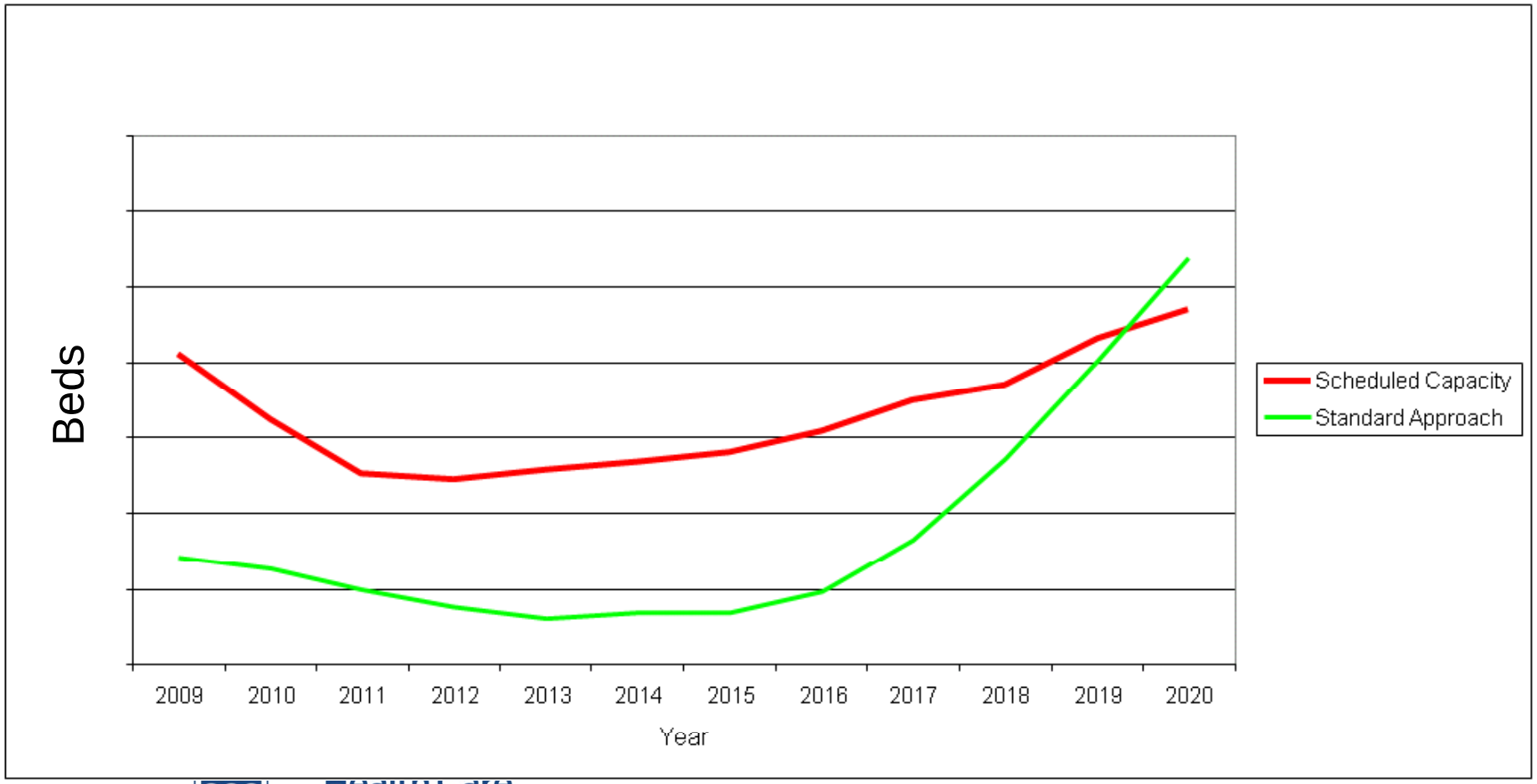
Using the Simulation to Determine Capacities

- To determine “optimal” capacities we need to simulate
  - Both arrivals and lengths of stay are unknown
- Capacities are determined by iteratively running the simulation and adjusting resource levels
  - Stopping conditions are determined by the service criteria
  - The service criteria we used was that 85% of clients are placed within 30 days.

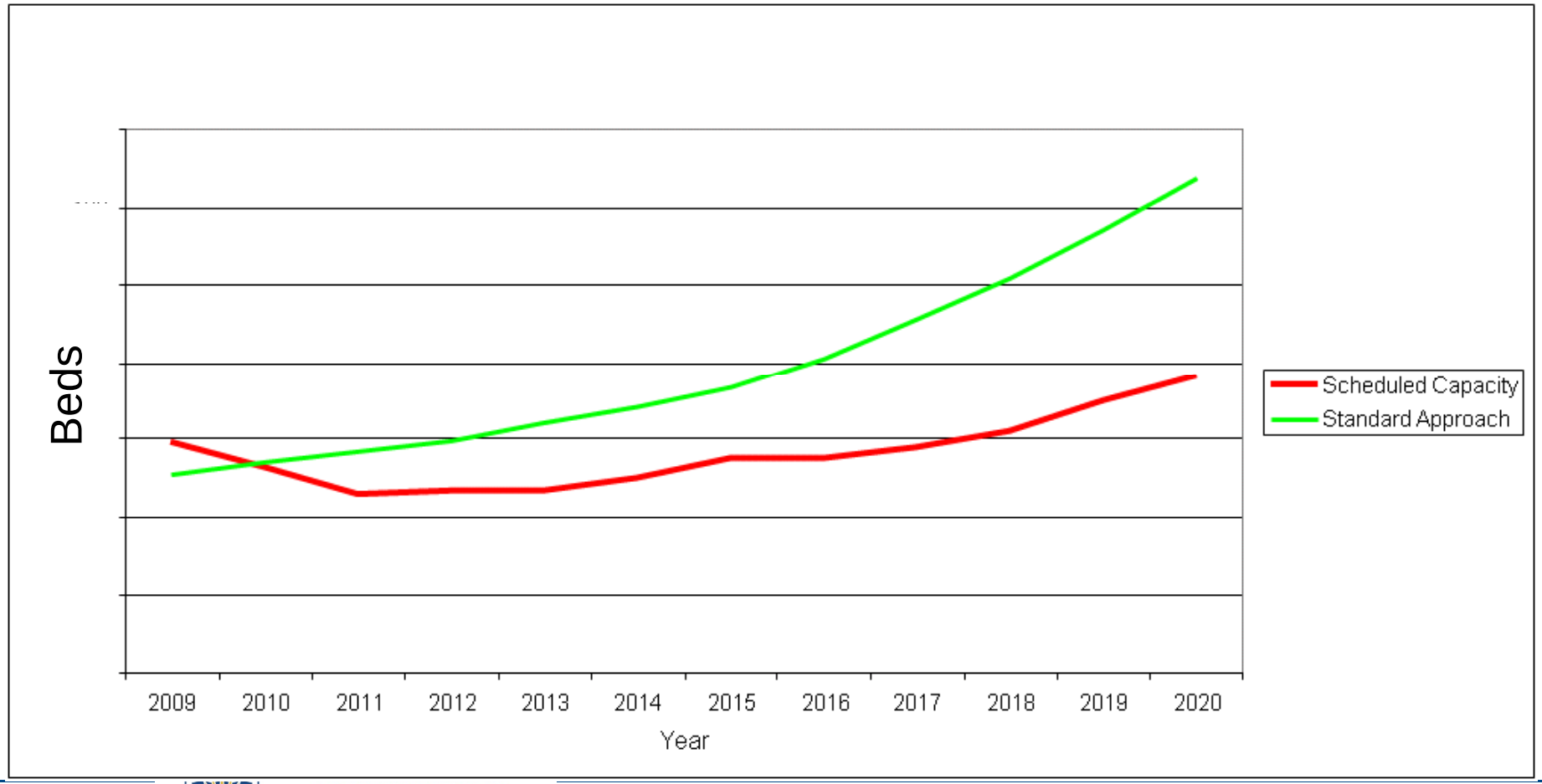
Sample Results



Limitations of Ratio Based Approach



Limitations of Ratio Based Approach



Some Observations

- Ratio based plans and service base plans differ
- Managers should not relax acuity standards if there is excess capacity
  - Will extend LOS and invalidate forecasts

Concluding Remarks

Some Observations

- Operations Research methods can significantly improve health care delivery
  - They provide a systematic way to address system challenges and issues
  - They raise pertinent questions and produce relevant answers
- There is a growing interest in health care problems in the OR research community
  - Health care problems are challenging and can produce good basic and applied research
- Portable applications and models are desirable
- Challenge (for health service researchers): investigate the impact of operational improvements on health care outcomes

Key Messages Regarding Health Care OR

- What gets measured gets done; but be sure the right thing is being measured
- Assumptions must be challenged
- Investment decisions should not be made without careful analyses
- Health care managers must be sure that appropriate data is collected and saved
- Operations Research is more than simulation

Conference Announcement

Operations Research and Lean Health Care; Implementation Successes and Challenges

Vancouver - April 23-24

Sponsored by MITACS, the CHCM and the CIHR Team in Operations Research in Quality Cancer Care

http://www.chcm.ubc.ca/VancouverConference.cfm