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# Managing Health Care Operations

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## Amazing Fact

The current average LOS for patients in a BC region is 8 days. If it can be reduced to 7 days, 9777 additional patients can be served each year!

*How do we know this?*  
*How do we achieve this?*



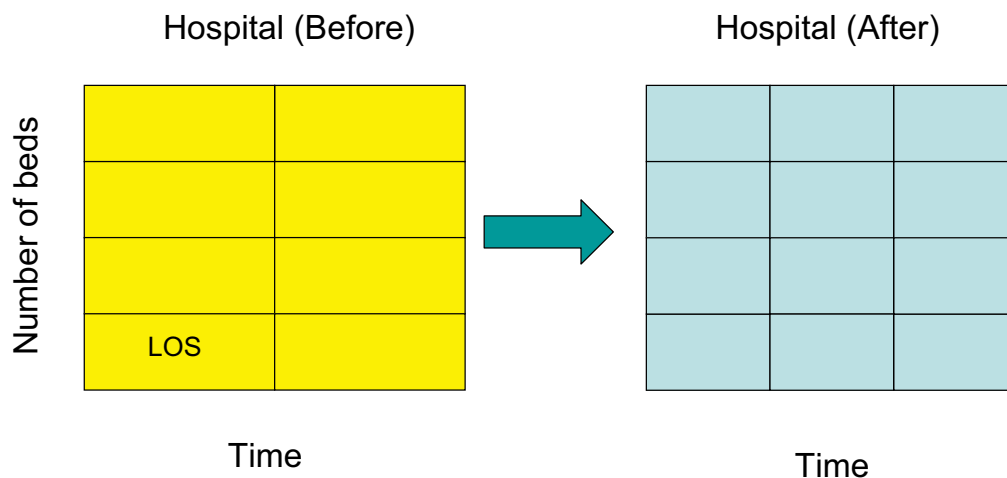
## Some Answers

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- Currently the HA has approximately 1500 acute beds and the average LOS is 8 days.
  - This means that average daily *throughput* is  $1500/8 = 187.5$  patients per day.
- If average LOS can be decreased to 7 days, average daily throughput becomes 214.3 patients per day
  - Net increase 26.8 patients per day
  - Equivalently 9777 patients per year!
- Benefits – increased access, shorter wait times and better outcomes.
- This cannot be done by cutting one day across the board.
- Operations Research models identify levers to achieve such a reduction.

## Effect of decreasing length of stay

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## Centre for Health Care Management



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## Centre for Health Care Management Mission

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- To enhance the delivery of health services in British Columbia and across Canada by:
  - Producing outstanding evidence-based health care management research
  - Providing outstanding health care management training
  - Training outstanding health care management researchers
  - Translating health care management research into practice

# Centre for Health Care Management

## Vision

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To be a world class centre for health care management research, education, and knowledge translation.

## Outline

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- Operations
- Processes
- Performance Measurement
- Capacity Management
- Bottlenecks
- Variability
- Summary

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## About Operations



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## What is operations management?

- *Operations* is the set of activities in an organization that produces goods and/or delivers services.
  - A fundamental difference; goods can be stored for future use, services cannot
    - An unsold box of cereal can be sold tomorrow.
    - An idle bed hour is lost for ever.
- **Managing operations Involves**
  - Analyzing Processes
  - Ensuring Quality
  - Planning
  - Scheduling Resources
  - Procuring Resources
  - Managing Inventory

# What is Operations Research?

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- A systematic way of thinking about operations.
- Focus on both tactical and strategic problems.
- A set of mathematical tools to quantify, represent and improve system performance.
- Tools – Optimization, simulation, modeling, and forecasting
- Operations researchers are mathematical efficiency experts – *John Blake*
- The Science of Better - *Informs*

## Key Themes

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- Excellent operations provides better patient care through:
  - shorter wait times
  - increased throughput
  - more efficient utilization of resources
- Excellent operations requires measurement and fact based decision making
  - If you're not keeping score, you're only practicing.
- Wise managers devote time to analysis
  - Think then do!
- To manage complex systems requires understanding the interrelationships between all entities
  - “For want of a nail .. the kingdom was lost”
- Operations management identifies the levers for improving system performance.

# A Complex Integrated System

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*For want of a nail the shoe was lost.  
For want of a shoe the horse was lost.  
For want of a horse the rider was lost.  
For want of a rider the battle was lost.  
For want of a battle the kingdom was lost.  
And all for the want of a horseshoe nail.*

Source: Mother Goose? Benjamin Franklin?

Question: Why was the kingdom lost? What was the root cause?

## Operations: Two views

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- Operations Strategy sets broad goals for the organization at several points throughout the year
- Operations Tactics deal with execution of the strategy on a day to day basis
- Executives set strategy, managers implement tactics
- Example – A BC Health Authority
  - Deciding which hospitals should perform which surgery types is *strategic*
  - Developing and managing surgery and staff schedules is *tactical*
- Different tools and timelines are relevant to each.
- Question to ponder:
  - What are examples of tactical and strategic decisions in your organizations?

## The Process Perspective

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- A *process* is a collection of tasks connected by flows of items, people and/or information that *transforms inputs into outputs*
- Some health care processes:
  - The admissions process transforms an arrival to an admitted patient.
  - The portering process transforms a patient (or materials) in one area to a patient or materials in another (more desirable) area
  - The ER process transforms emergency cases to hospital admissions or treated cases
  - The staffing process transforms an unfilled slot into a filled slot

## Why Analyze Processes?

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- To understand them
- To determine their capabilities
- To improve them
- To redesign them
- To set performance goals

# Process Improvement

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- *As Is Analysis* – Understand the current process.
- *Process mapping* - Construct a *process flow diagram*.
  - Specify what the process is supposed to do.
  - Determine what flows through the process.
  - Determine all activities in the process, how they are interrelated and how items flow through them.
  - Identify information flows.
  - Since most health care processes support multiple types of patients, there will usually not be a fixed routing through the map, but a conditional routing depending on the patient's characteristics and needs.
- Developing a map of a process can lead to new insights into how to manage the process.
  - Most operations improvement projects start with process mapping.
- The *As Is Analysis* lays the foundation for the *To Be Analysis*.

## Process Flow Diagram Elements

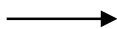
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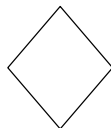
Tasks, activities or operations



Buffers or Queues

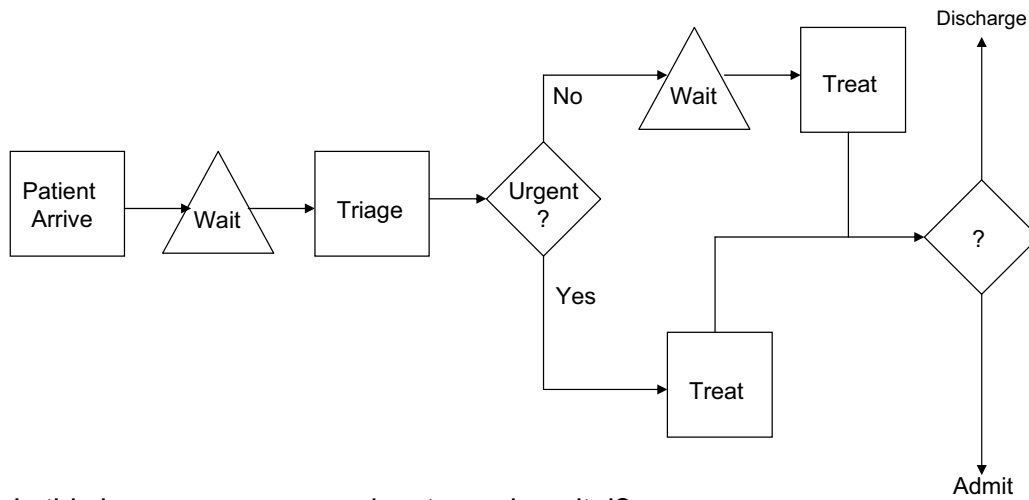


Flows



Decisions

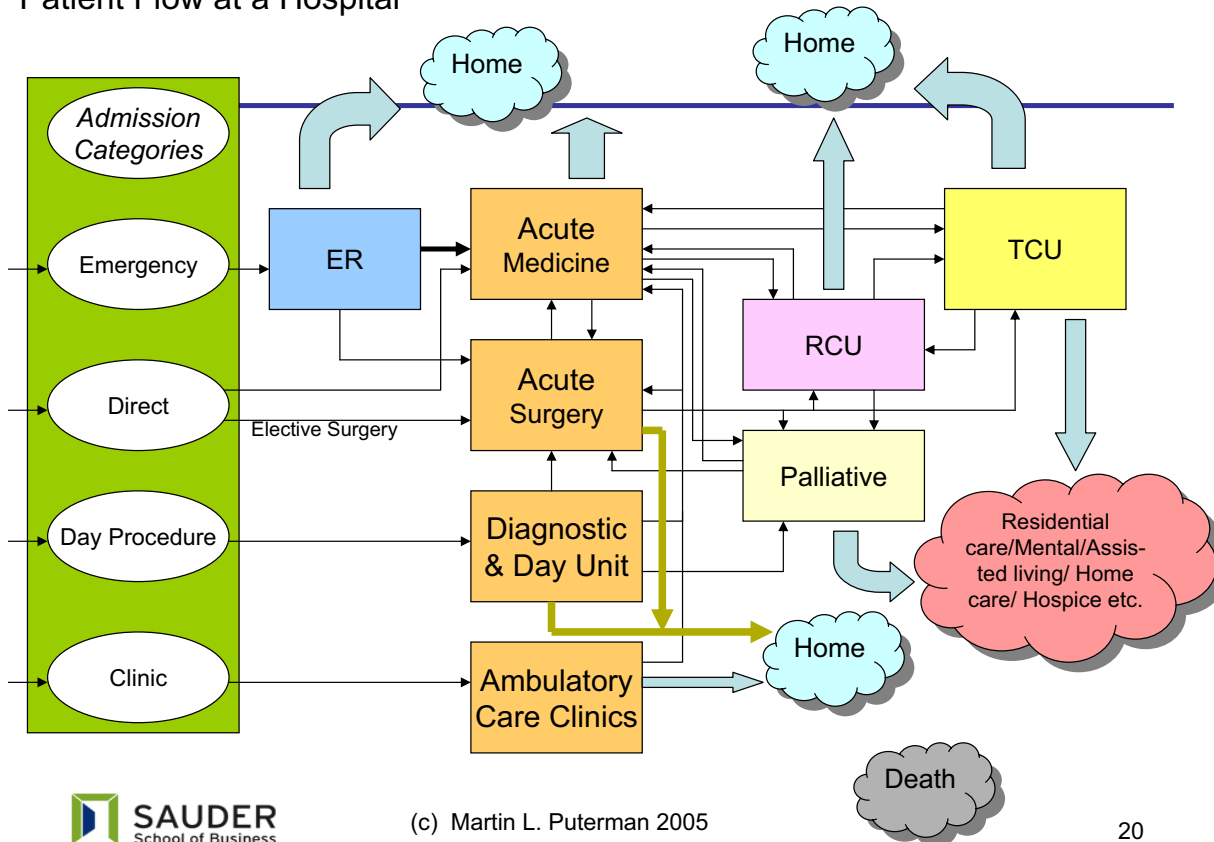
# A Hypothetical Emergency Room Process



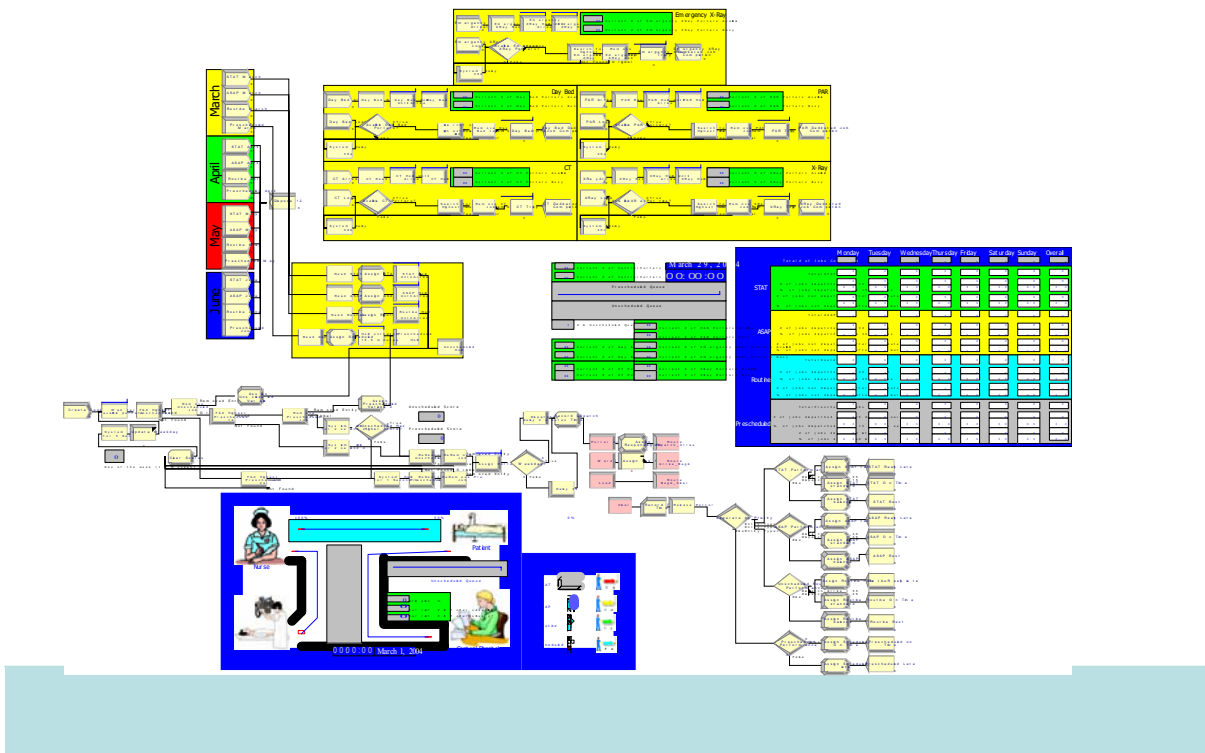
Is this how emergency works at your hospital?

Is this the best way to do this?

## Patient Flow at a Hospital



## A more complex process



## Flow through a process

- The basic entity that moves through a process is a *flow unit*.
- At any time in a process a flow unit may be
  - undergoing an activity
  - waiting in a buffer to undergo an activity
- Example: A passenger going through security at Vancouver International Airport.
  - A passenger is the flow unit
  - The passenger may either be actively involved in some portion of the screening process, or
  - Waiting to undergo a screening activity.



# Measuring Process Performance

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*Whenever you can, count.*

Francis Galton

## Three Key Process Metrics

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- *Flow Time (Cycle Time)*- The time it takes for a flow unit to move through the process.
  - This measures the time it takes for the process to convert an input to an output
  - In a hospital, this is Length of Stay
- *Inventory* - The number of flow units within the process boundaries at any particular time
  - In a hospital, this is the number of occupied beds
- *Flow Rate (Throughput Rate)*- The rate at which flow units flow through (leave) the process
  - May differ depending on which portion of the process is viewed
  - This is the rate at which patients leave the hospital

# Other Process Metrics

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- Process Capabilities
  - Capacity
  - Quality
  - Service levels
    - Percentage of flow units that spend more than or fewer than x units of time within the process
    - This looks at more than just averages
- Utilization
  - Capacity Used/Total Capacity

## The Fundamental Rule of Processes Little's Law

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- In a process, the average flow time, average throughput rate and the average inventory are related by:

$$I = R \times T$$

Average Inventory = Average Throughput Rate  $\times$  Average Flow Time

- Example: An ER serves 1200 patients in a 24 hour day. On average there are 75 patients in the ER. What is the average time a patient spends in the ER?

What is the flow unit ?

Throughput = ??

Inventory = ??

Flow Time = ??

## Little's Law Example

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- The ER serves 1200 patients in a 24 hour day. On average there are 50 patients in the ER. What is the average time a patient spends in the ER?

The flow unit is a *patient*.

Throughput =  $R = 1200/24 = 50$  patients/hr

Inventory =  $I = 75$  patients

Flow Time =  $T = I/R = 75/50 = 1.5$  hrs

- So a patient spends on average 1.5 hours in the ER.

## Little's Law - Example 2

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- The diagnostic imaging department requires 3 weeks on average from when a requisition is filed to when the scan is completed. It completes 15,000 scans per year. How many patients are waiting for scans?

- Solution:

Throughput =  $R = 15000/50 = 300$  scans/week

Flow Time =  $T = 3$  weeks

Inventory =  $I = R \times T = 300 \times 3 = 900$  patients

- On average 900 patients are waiting for scans

# Little's Law Consequences

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- If we know two of inventory, throughput or cycle time for a system, we can determine the third.
- A manager is not free to independently control flow time, throughput and inventory levels! Once two are chosen, the third is determined.
- Example: How can we reduce the waiting time (cycle time, T) for diagnostic imaging.
  - Recall **Waiting Time = Inventory/Throughput Rate** ( $T=I/R$ )
  - We can increase throughput rate and keep waiting list the same size.
  - We can reduce waiting list and not change throughput.
  - We can reduce waiting list and increase throughput.
  - How can we do this?

# Obstacles to Process Improvement

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- Most processes span across units or organizations.
  - Consequently no one knows how the whole process works.
- To achieve improvement, you must work with people who may have conflicting objectives. This is frequently impossible unless you:
  - Have *buy-in from senior management*.
  - Can arrange for a single person or group to “*own*” the process.
  - Can *start small*, with winning projects before undertaking a radical change.
  - Can build up a level of *trust* between the different stakeholders.
  - Arrange for the different units to have *incentive systems that are compatible* with the overall process.

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## Capacity Management and Bottlenecks



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### What is the capacity of a process?

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- Capacity is the maximum *rate* at which a process can produce output.
- What is the capacity of a 40 seat restaurant?
  - It depends on how long customers remain there.
  - If the average length of a meal is 30 minutes, then it is 80 customers per hour.
  - If the average length of a meal is two hours, it is 20 customers per hour.
- What is the capacity of a 40 bed ward?
  - It depends on how long patients remain in the ward.
- What is the capacity of a CT scanner?
  - It depends on how long scans take.
- What is the capacity of a porter?
  - It depends how long moves take.

# Capacity Management

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- Capacity management focuses on **increasing process throughput** by
  - utilizing capacity more efficiently
  - adding capacity (when necessary)
  - matching capacity with demand
- Capacity can be measured for both physical equipment and human capital
- Why is capacity management important?
  - It reduces wait times
    - In most public sector systems, capacity limits throughput
    - For a given queue length, increasing throughput reduces wait times (Little's Law again)

# Theoretical Capacity

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- The theoretical capacity of a process is the maximum number of flow units that can be processed per unit time if it is fully utilized.
- Examples
  - A process requires 10 minutes per flow unit
    - The theoretical capacity is 6 units per hour
  - A process requires 15 minutes per batch and batches consist of 10 units
    - The capacity is 40 units per hour.
- The capacity of a process depends on the capacity of its components and how they are interrelated.

# Some Definitions

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- The basic capacitated units
  - resources
  - activities
  - Basic relationship – *resources perform activities*
- Activity – A step in a process
- Resource unit (resources) – a person or piece of equipment that performs an activity
- Unit load – length of time required to process a flow unit
- Resource pool – a collection of interchangeable resource units that performs one or more activities
- Example – Diagnostic Scanning
  - Activities
    - Get patient, prepare patient, set up scanner, scan, verify, return patient
  - Resource units
    - Porters, technologists, tech aids, the CT scanner

## Computing Theoretical Process Capacity An Example

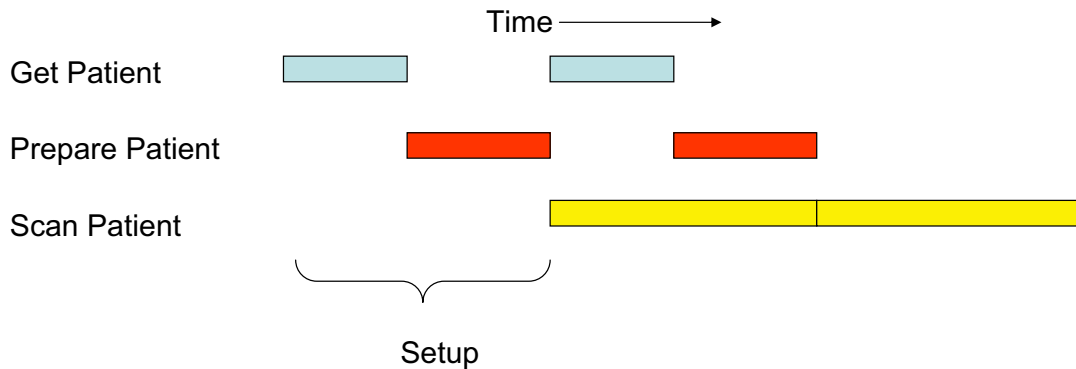
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- Scanning an inpatient requires the activities “Get Patient”, “Prepare Patient” and “Scan”.
- The porter “Gets The Patient”, the tech aid “Prepares the Patient” and the technologist “Scans”.
- The flow unit is a patient.

Resource Pool	Unit Load (mins/unit)	Theoretical Capacity (units/hour)
Porter	6	10
Tech Aid	10	6
Technologist and Scanner	15	4

- What is the theoretical process capacity?
- 4 units per hour
- The technologist is called the theoretical **bottleneck**
- **The process capacity is determined by the bottleneck.**
- What would happen if each resource worked at its capacity?

# Representing Processes – A Gantt Chart



Time to perform  $n$  tasks = setup +  $n$  \* bottleneck unit load + wrap up

In above example; the time to perform 2 scans is  $16 + 2 * 15 + 0 = 46$  minutes

## The Bottleneck Activity Limits Process Capacity

- Increasing the throughput rate of non-bottleneck activities does not increase process throughput
  - Having the porter work faster does not improve CT Scanner operations (but may have other impacts)
- Can increase capacity by off loading work from the bottleneck
  - Avoid redundant scans or use other diagnostics
- Increase capacity by avoiding rework at the bottleneck
  - insure accurate scans the first time
- Whenever a bottleneck is not working, throughput is reduced
  - Avoid starving the bottleneck
    - Control no shows and patient arrivals
  - Avoid blocking the bottleneck
    - Remove patients from scan room ASAP

# Capacity Utilization

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- Capacity utilization =  $\text{Throughput} / \text{Theoretical Capacity} (*100\%)$ 
  - Capacity utilization measures the fraction of time a resource is used to serve users
  - Throughput equals the average number of units processed over a given time period
- Capacity Utilization of all resources rarely equals 100%.
  - When does it?
- Example again: The process described above

Resource Pool	Theoretical Capacity
Porter	10
Tech Aid	6
Technologist	4

  - The process capacity is 4 units per hour
  - Utilization of the porter is 40%, the tech aid is 66.6% and the technologist is 100%

## Capacity Utilization (Adding a Scanner)

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- Suppose instead we had 2 scanners and 2 technologists carrying out the test activity so that the theoretical capacities are now

Resource Pool	Unit Load	Unit Capacity	Pool Size	Pool Capacity
Porter	6	10	1	10
Tech Aid	10	6	1	6
Technologist	15	4	2	8
- What is the theoretical capacity of this system?
  - 6 units/hour
- The bottleneck has shifted from the Technologist to the Tech Aid
- Utilization of the porter is 60%, of the tech aid is 100% and the technologists and scanners is 75%.
- Our discussion so far has ignored *variability* in processing times and arrival times.
- How would you increase the capacity of this system?
- Is a balanced system most efficient?

# “Actual” Throughput

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Actual throughput =  
number of units processed / time process observed.

Process utilization =  
actual throughput / theoretical capacity

- These may vary on a day to day basis.
- When processes are not fully utilized, capacity is “lost”, throughput is reduced and waiting times increase.

## Factors Affecting Actual Throughput

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- Patient Mix
- Planned Unavailability
  - Staff Schedules
  - Maintenance Schedules
- Unplanned Unavailability
  - Absence
  - Injuries
  - Machine Breakdowns
- In Process Variation
  - Idle time due to starvation
  - Idle time due to blockage
    - full buffers
  - Variation in process times
- Learning
- Quality
  - Rework

# Managing Capacity

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- Enhance performance of the bottleneck
  - Decrease work content of the activity performed by the bottleneck resource
  - Move work content to non-bottleneck resources
    - These require flexibility in non-bottleneck resources (workers and/or equipment)
  - Add resources (workers and/or equipment) to the bottleneck
  - Increase scheduled availability (shifts) at bottleneck
- How
  - Work faster - incentives and training
  - Do it right the first time - product and process design
  - Change patient mix – add and specialize equipment
  - Cross train staff - enhances flexibility
  - Subcontract work - remove load from bottleneck

# Improving Actual Throughput

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- Decrease resource idleness
- Avoid blockages
  - Increase downstream buffer sizes
  - Empty downstream buffers faster
- Avoid resource starvation
  - Ensure work is always available in front of bottleneck by increasing upstream flow
  - Increase buffer sizes ahead of the bottleneck
- Breakdown and Maintenance Reduction
  - Use preventive maintenance scheduled outside periods of availability
  - Investigate causes of breakdowns and address them
  - Improve worker training
- Setup and changeover reduction
  - Increase batch sizes (this may increase inventory and cycle time)
  - Manage product mix
  - Arrange material so it is easily accessible
  - Reduce setup times (run similar jobs in sequence)

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# Variability and Queueing



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## About Variability

- Predictable variability
  - Over time, quantities differ from their mean level in a systematic way
    - Seasonal effects
    - Time of day effects
    - Trends
- Unpredictable variability
  - Unexplained variation due to un-measurable factors
    - Throw of a dice
    - Times between arrivals of patients
- Most phenomenon contain both sources of variability
  - Hospital – emergencies and scheduled surgeries
- Variability increases wait times and waiting lists!
- Queuing theory studies the effect of variability

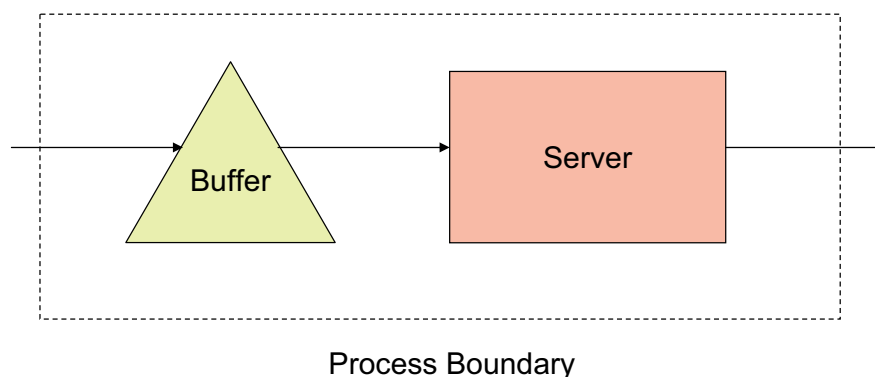
# Quantifying Variability

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- Probability Statements
  - Prob(  $X = 4$  )
  - Prob(  $20 < T \leq 30$  )
- Variances and Standard Deviations
  - These lead to probability statements
- Coefficient of Variation
  - Standard Deviation/Mean
- By quantifying variability we can make quantitative performance guarantees
  - Example: 80% of patients will wait no more than 10 days for a CT scan

## A Single Phase Service Process

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A queue forms in a buffer

## Some results for systems with variability

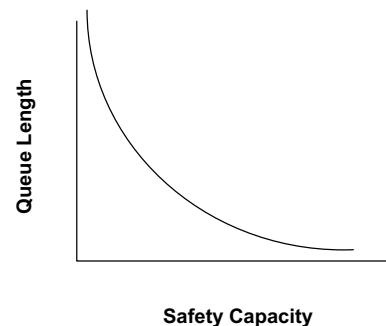
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- As the safety capacity ( $Service\ Rate - Arrival\ Rate$ ) decreases:
  - waiting time increases dramatically!
  - queue lengths become very long!
- When there is variability in inter-arrival times and service times and when the arrival rate and capacities are close, waiting times and queue lengths will be very long.
- In addition, as the interarrival times and service times become more variable, queue lengths and waiting times increase.

## Queueing Illustration

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- Data
  - Arrival Rate = 20 patients/hr
  - Service Rate = 25 patients/hr
- Safety Capacity =  $25 - 20 = 5$  patients/hr
- Performance measures
  - System Utilization = 80%
  - Average Time in System = .2 hrs
  - Average Number in Queue = 3.2
- Suppose arrival rate increases to 24
  - System Utilization becomes 96%
  - Average Time in System = 1 hr
  - Average Number in Queue = 23
- Suppose arrival rate increases to 24.9
  - System Utilization becomes 99.6%
  - Average Time in System = 10 hrs
  - Average Number in Queue = 248!



# Summary

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- Managing operations is an important component of the hospital manager's job
- This talk has provided a range of directly applicable approaches for managing operations
  - Process Analysis
  - Performance Measurement
  - Capacity Analysis
  - Operations Research
- Key points
  - Map your processes
  - Measure performance
  - Identify bottlenecks and manage them wisely
  - Use operations research methods
  - Step back and analyze!

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## Extra Slides

# Process Analysis Overview

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- Identify what the process is intended to do
- Define the process entities
  - inputs, flow units, activities and outputs
- Map the process
- Determine performance measures
- Set process goals
- Determine process capabilities
- Determine process current performance (baseline)
  - Collect data
- If goals achieved :). If goals not achieved, identify why.
- Brainstorm potential improvements; revise process maps and estimate their impact either through
  - calculations based on *average performance*, or
  - simulation models that account for *process variability*

# Service Process Attributes

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- Arrivals
  - Average job arrival rate (patients/time)
  - Average customer inter-arrival time
- Services
  - Average processing rate
  - Number of servers in resource pool
  - Process service rate
- System characteristics
  - Traffic Intensity
    - $i = \text{Arrival rate} / \text{service rate}$
  - Safety Capacity
    - $s = \text{Process Service Rate} - \text{Process Arrival Rate}$
- Performance Measures
  - Average waiting time (in queue)
  - Average time spent at the server
  - Average flow time (in process)
  - Average queue length
  - Average number of customers being served
  - Average number of customers in the process