
Business Process Management - Quantitative



Knowledge objectives

1. Recognize the importance of measuring processes
2. Enumerate the four performance measures
3. Enumerate different measures of time
4. Enumerate different kinds of cost
5. Distinguish quality measures regarding process and product
6. Enumerate what flexibility can affect
7. Explain the correlation between the four performance measures
8. Enumerate three process analysis techniques
9. Explain the drawbacks of flow analysis
10. Explain the drawbacks of queue theory
11. Explain the drawbacks of process simulation
12. Explain what cycle time efficiency is
13. Explain Little's formula
14. Explain the reasons to have queues
15. Identify the statistical distribution of the time between the arrival of jobs to a process
16. Enumerate the process simulation steps



Understanding Objectives

1. Recognize when flow analysis cannot be performed
2. Given a process model and its statistics, calculate its cycle time efficiency
3. Given a process model and its statistics, calculate the length of its queues, work-in-progress, cycle time, and the average time of a job in a queue
4. Given a process model, its statistics, and a list of jobs, simulate their execution



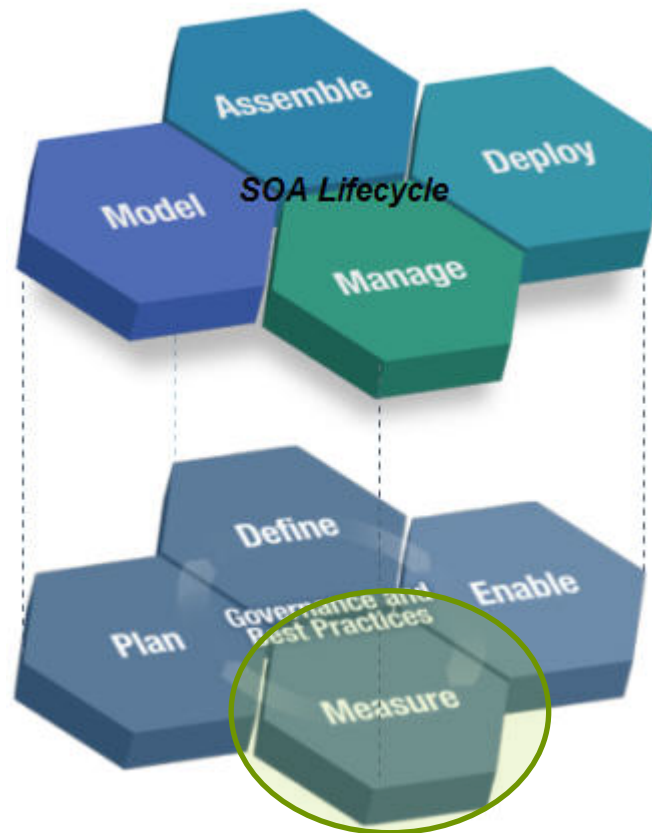
Key Performance Indicators

"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 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 stage of *science*, whatever the matter may be."

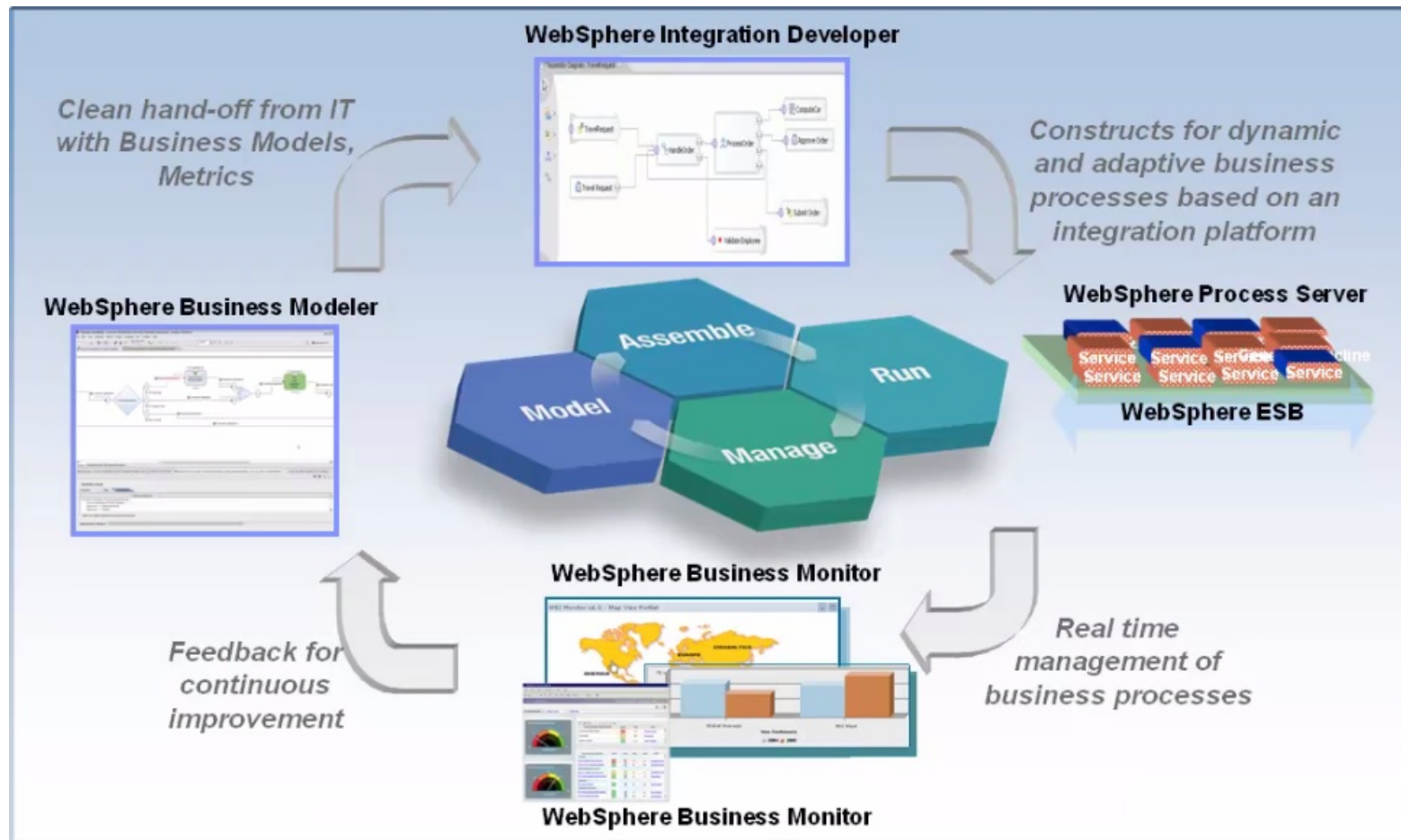
Lord Kelvin, 1883



SOA Governance



IBM WebSphere architecture



Performance measures: Time

- Cycle/Flow/Lead time (latency)
 - Processing/Service time
 - Waiting time
 - Queuing time
 - Contention (limited capacity)
 - External communication (waiting for client/partner)
 - Synchronization time
- Transport time



Performance measures: Cost

- Types of costs:
 - Fixed vs Variable
 - Per time unit vs Per use
 - Processing vs Management vs Support
 - Human vs System (Hw/Sw) vs External

- Cost models:
 - Activity Based Costing
 - Time-driven Activity Based Costing
 - Resource Consumption Accounting



Performance measures: Quality

□ Product

- Product meets specifications
- Promises made to customers and (reasonable) customer expectations are met
 - Satisfaction questionnaires
 - Number of complaints

□ Process

- Data and documents are handled correctly
- Decisions made in the process are correct
- Correct & timely information is provided to the customer

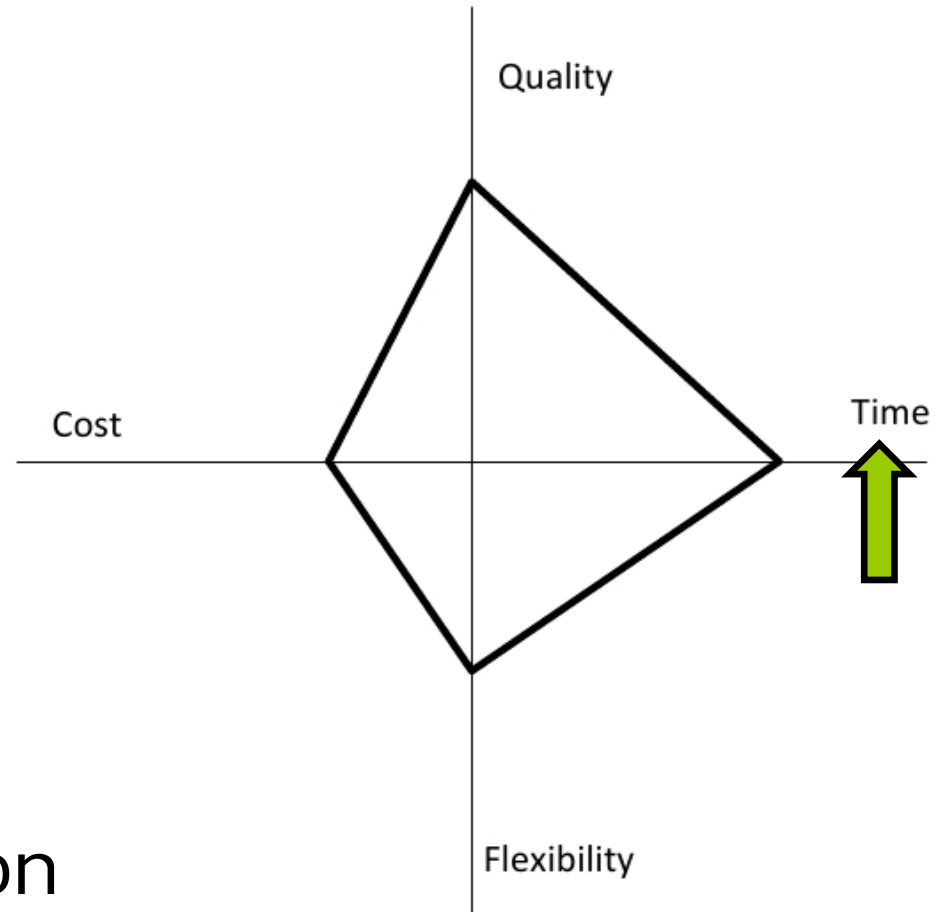


Performance measures: Flexibility

- Ability to react to changes
- Flexibility of
 - Resources
 - Ability to execute many tasks/new tasks
 - Process
 - Ability to handle various cases and changing workloads
 - Management
 - Ability to change rules/allocation
 - Organization
 - Ability to change the structure and responsiveness to demands of market or business partners



The Devil's Quadrangle



- Improve average
- Improve variance
- Improve perception
- Increase ability to meet objectives

From <http://fundamentals-of-bpm.org/>



Process Analysis Techniques

- ❑ Quantitative Flow Analysis
 - Does not consider waiting times due to resource contention
- ❑ Queuing Theory
 - Helps to balance the cost of increased capacity against the gains of increased productivity and service
- ❑ Process Simulation (Play out)
 - General purpose (measures any KPI)
 - Risk of oversimplifying
 - ❑ Behavior of resources
 - ❑ Cost model



Flow Analysis

□ Definitions:

- Cycle time: Difference between a job's start and end time
- *Cycle time analysis*: the task of calculating the **average** cycle time for an entire process or fragment
- Activity time = waiting time + processing time

□ Assumptions:

- The average activity times for all involved activities are available

□ In the simplest case a process consists of a list of activities on a sequential path

- The average cycle time is the sum of the average activity times

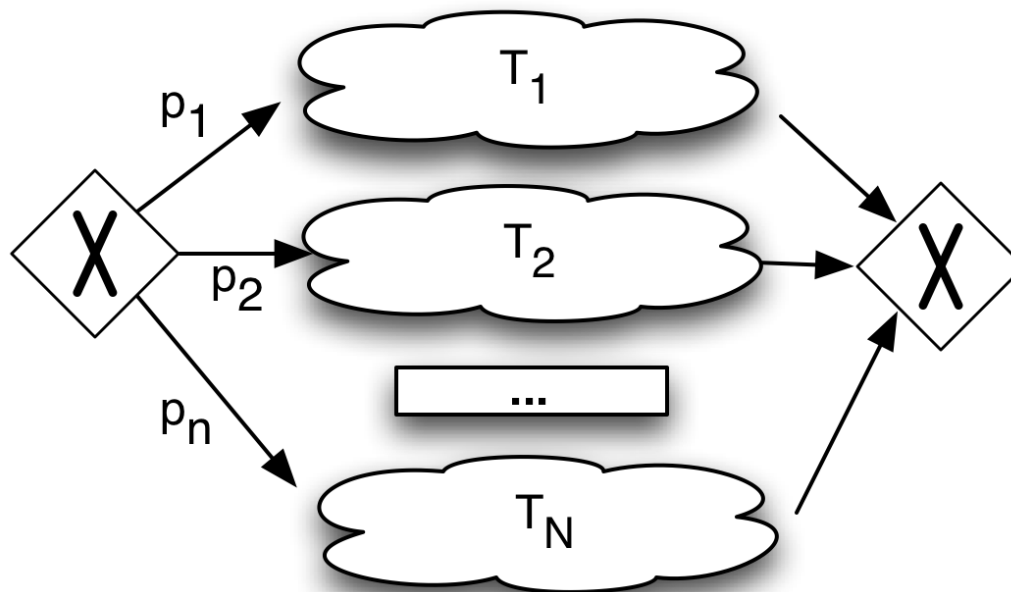
□ ... but in general we must be able to account for

- Alternative paths (XOR splits)
- Parallel paths (AND splits)
- Rework (cycles)

From <http://fundamentals-of-bpm.org/>



Alternative Paths

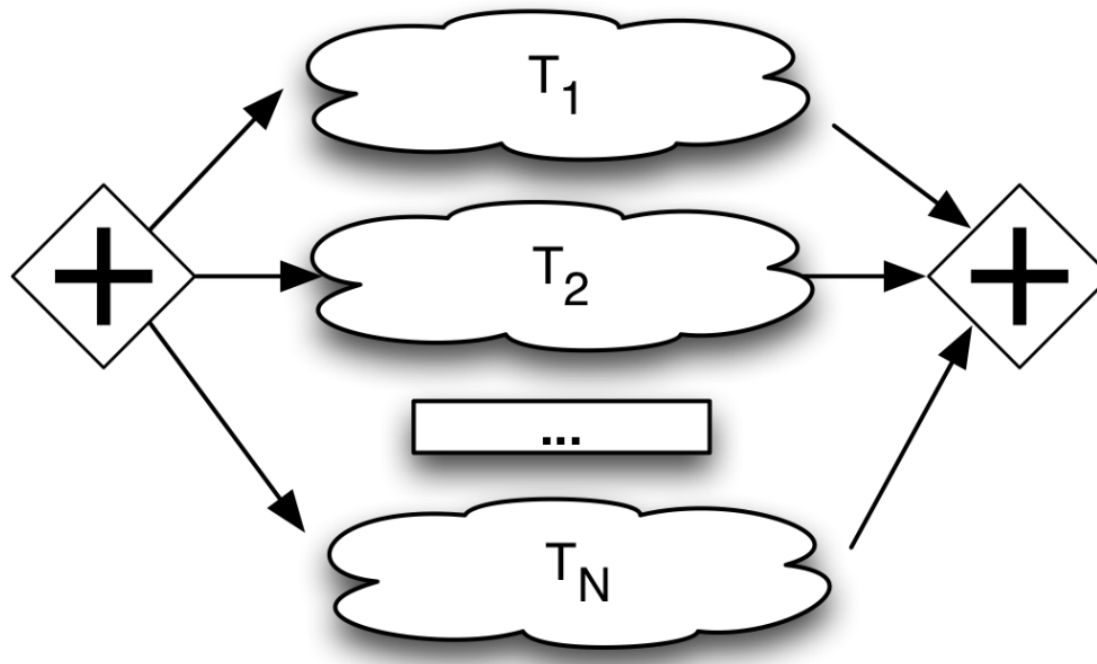


$$CT_{\text{alternative}} = p_1T_1 + p_2T_2 + \dots + p_nT_n = \sum_{i=1}^n p_i T_i$$

From <http://fundamentals-of-bpm.org/>
Inspired by a slide by Manuel Laguna & John Marklund



Parallel Paths

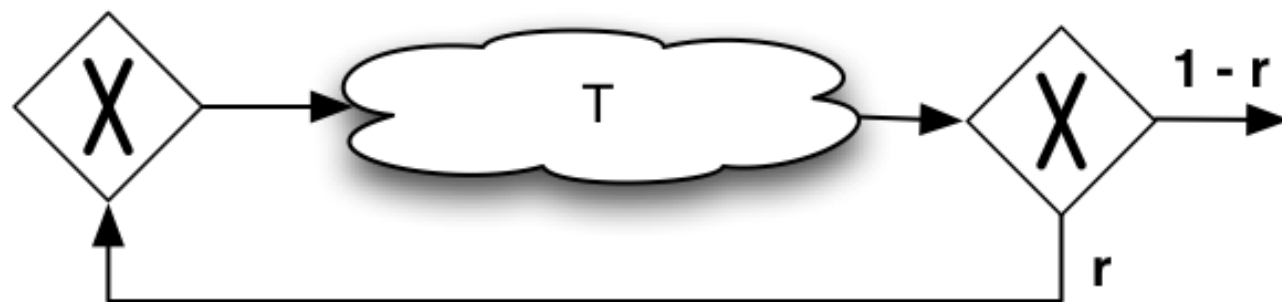


$$CT_{\text{parallel}} = \text{Max}\{T_1, T_2, \dots, T_M\}$$

From <http://fundamentals-of-bpm.org/>
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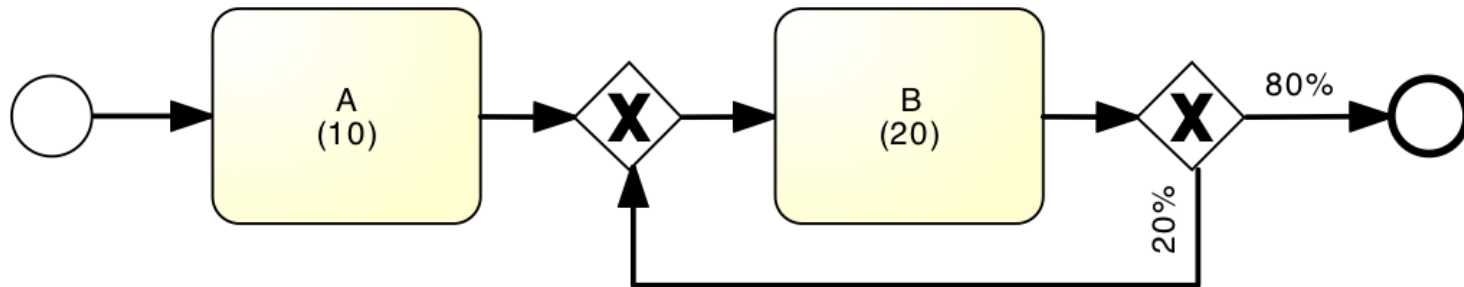
Rework



$$CT_{\text{rework}} = T/(1-r)$$



Rework example



From <http://fundamentals-of-bpm.org/>

Unitary cost:	20		
Rework probability:	0,2		
Expected iterations:	1,25		
Expected cost:	25		
Iteration	Probability	Added cost	Cummulative
1	0,8	16	16
2	0,16	6,4	22,4
3	0,032	1,92	24,32
4	0,0064	0,512	24,832
5	0,00128	0,128	24,9600
6	0,000256	0,03072	24,99072
7	0,0000512	0,007168	24,997888
8	0,00001024	0,0016384	24,9995264
9	0,000002048	0,00036864	24,9998950
10	4,096E-07	0,000081920	24,9999770



Cycle Time Efficiency

- Measured as the percentage of the total cycle time spent on value adding activities

$$\text{Cycle Time Efficiency} = \frac{\text{Theoretical Cycle Time}}{\text{CT}}$$

CT = cycle time as defined before

Theoretical Cycle Time (TCT) = cycle time if we only counted value-adding activities and excluded any waiting time or handover time

- Count only *processing times*

From <http://fundamentals-of-bpm.org/>
Inspired by a slide by Manuel Laguna & John Marklund



Work-In-Progress

- ▣ Measured as the average number of jobs that are running (i.e., started but not yet completed)

Little's Formula

$$L = \lambda \cdot W$$

W = cycle time as defined before

λ = arrival rate (number of new jobs per time unit)



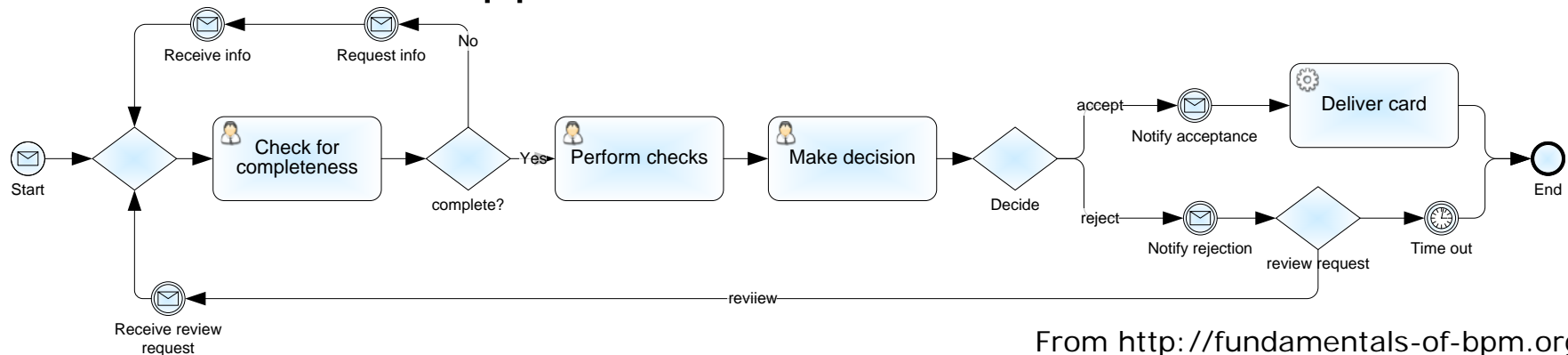
Flow Analysis discussion

□ Generalization:

- Calculating cost-per-process-instance
- Calculating error rates at the process level
- Estimating capacity requirements

□ Limitations

- Cycle time analysis does not consider waiting times due to resource contention
 - Queuing analysis and simulation address these limitations and have a broader applicability
- Cannot be applied to all flows

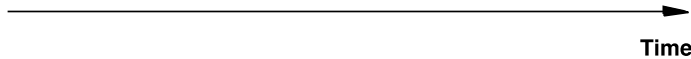


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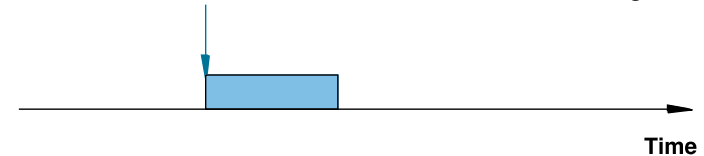


Delay is Caused by Job Interference

Deterministic traffic



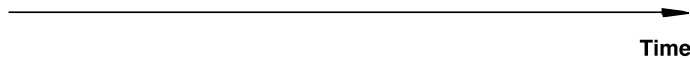
Deterministic arrivals, variable job sizes



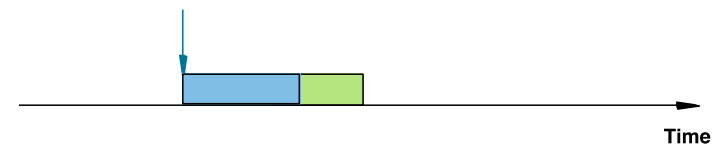
Bursty traffic



Variable but spaced apart traffic

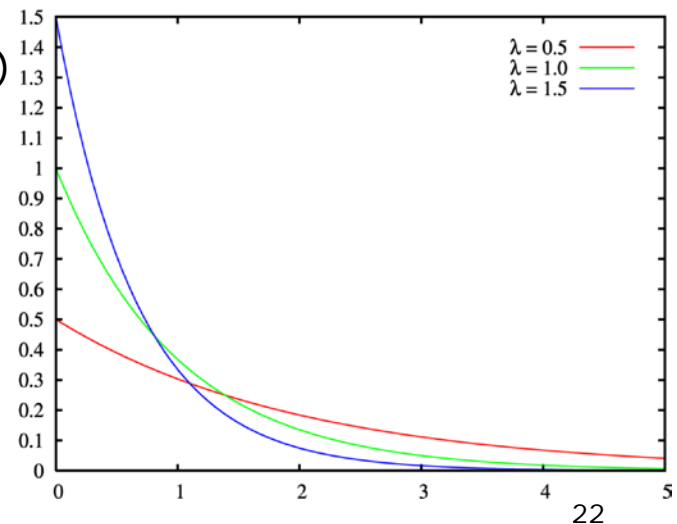


High utilization



The Poisson Process

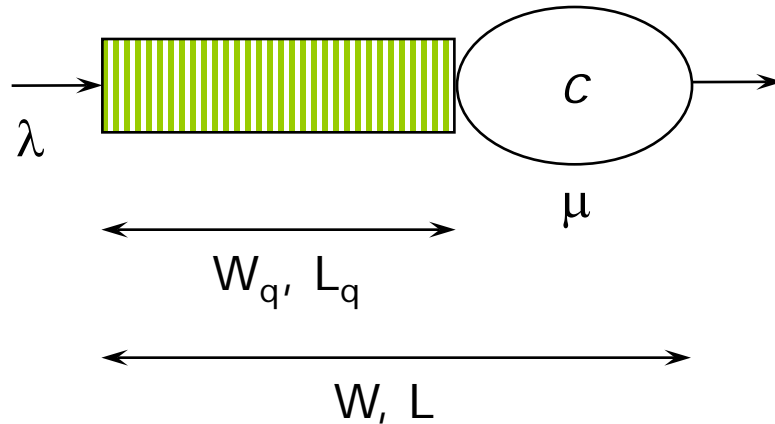
- Common arrival assumption in many queuing and simulation models
 - The times between arrivals are independent, identically distributed and exponential
 - $P(\text{arrival} < t) = 1 - e^{-\lambda t}$
 - Key property: The fact that a certain event has not happened tells us nothing about how long it will take before it happens
 - E.g., $P(X > 40 \mid X \geq 30) = P(X > 10)$



From <http://fundamentals-of-bpm.org/>
By Manuel Laguna & John Marklund



Queuing theory basics



- ▣ λ (mean arrival rate) = average number of arrivals per time unit
- ▣ μ (mean service rate) = average number of jobs that can be handled by one server per time unit
- ▣ c = number of servers

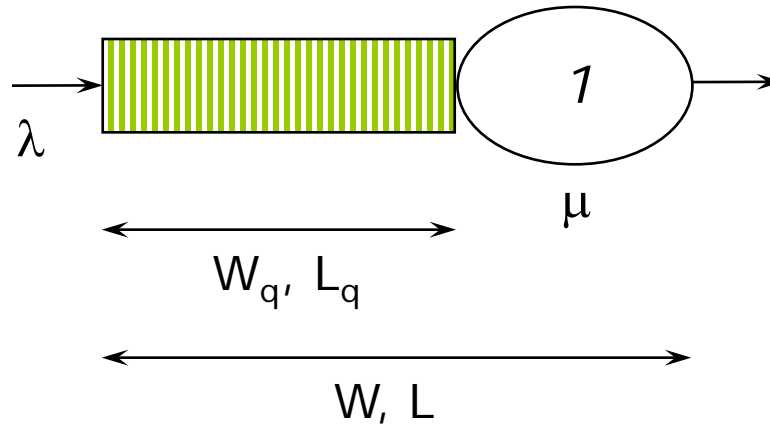
Given λ , μ and c , we can calculate :

- ▣ ρ = occupation rate
- ▣ W_q = average time in the queue
- ▣ W = average time in the system (i.e. CT)
- ▣ L_q = average jobs in the queue (i.e. length of queue)
- ▣ L = average jobs in the system (i.e. WIP)

From <http://fundamentals-of-bpm.org/>
By Wil van der Aalst



M/M/1 queue



$$\rho = \frac{\text{Capacity Demand}}{\text{Available Capacity}} = \frac{\lambda}{\mu}$$

$$L = \rho / (1 - \rho)$$

$$W = L / \lambda = 1 / (\mu - \lambda)$$

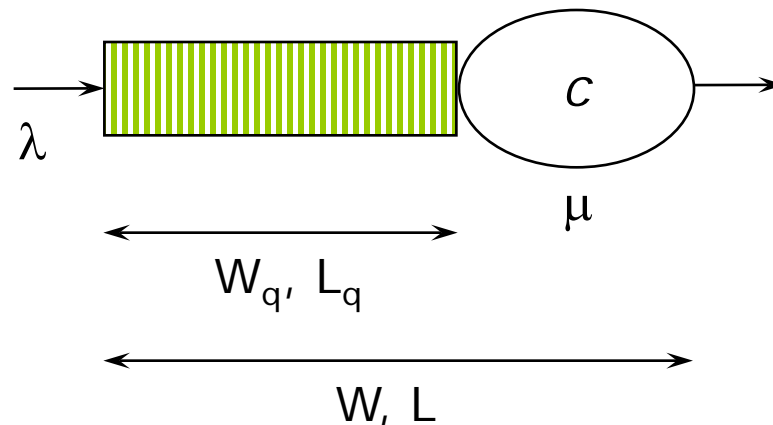
$$L_q = \rho^2 / (1 - \rho) = L - \rho$$

$$W_q = L_q / \lambda = \lambda / (\mu(\mu - \lambda))$$

From <http://fundamentals-of-bpm.org/>
By Manuel Laguna & John Marklund



M/M/c queue



$$\rho = \frac{\text{Capacity Demand}}{\text{Available Capacity}} = \frac{\lambda}{c * \mu}$$

Little's Formula $\Rightarrow W_q = L_q / \lambda$

$$W = W_q + (1/\mu)$$

Little's Formula $\Rightarrow L = \lambda W$

From <http://fundamentals-of-bpm.org/>
By Manuel Laguna & John Marklund



Process Simulation

- Drawbacks of queuing theory:
 - Generally not applicable when system includes parallel activities
 - Requires case-by-case mathematical analysis
 - Assumes “steady-state” (valid only for “long-term” analysis)
- Process simulation is more versatile
 - Run a large number of process instances, gather data (cost, duration, resource usage) and calculate statistics from the output



Process Simulation steps

1. Model the process (e.g., BPMN)
2. Produce the simulation model (i.e., add simulation info to the process model)
 - ▣ Based on assumptions or better based on data (logs)
3. Run the simulation
4. Analyze the simulation outputs
 1. Process duration and cost statistics and histograms
 2. Waiting times (per activity)
 3. Resource utilization (per resource)
5. Repeat for alternative scenarios



Elements of a simulation model

- ❑ The process model including:
 - Events, activities, control-flow relations (i.e., flows, gateways)
 - Resource classes (i.e., swimlanes)
- ❑ Resource assignment
 - Mapping from activities to resource classes
- ❑ Processing times
 - Per activity or per activity-resource pair
- ❑ Costs
 - Per activity and/or per activity-resource pair
- ❑ Arrival rate of process instances
- ❑ Conditional branching probabilities (XOR gateways)

From <http://fundamentals-of-bpm.org/>



Activity

- ❑ *Objective: Understand the three process analysis techniques*
- ❑ *Tasks:*
 1. (10') *Individually solve one exercise*
 2. (15') *Explain the solution to the others*
 3. *Hand in the three solutions*
- ❑ *Roles for the team-mates during task 2:*
 - a) *Explains his/her material*
 - b) *Asks for clarification of blur concepts*
 - c) *Mediates and **controls time***



Summary

- ❑ Process performance measures
 - Time
 - Cost
 - Quality
 - Flexibility
- ❑ Flow analysis
- ❑ Queue theory
- ❑ Process simulation



Bibliography

- M. Dumas et al. *Fundamentals of business process management*. Springer, 2013
- W. van der Aalst. *Process mining : discovery, conformance and enhancement of business processes*. Springer, 2011
- B.D. Clinton and A. van del Merwe. *Management Accounting: approaches, Techniques, and Management processes*. Cost management, 20(3), 2006



Resources

- ❑ Related to process simulation
 - ITP Commerce Process Modeler for Visio
 - Progress Savvion Process Modeler
 - IBM Websphere Business Modeler
 - Oracle BPA
 - ARIS
 - ProSim
 - Signavio

