Discrete Event Simulation

- Goals of this class
  - Understand discrete event simulation
  - See how it applies to assembly systems
  - Understand its strengths and weaknesses
  - See some statistics about real systems

"Stoppage? What stoppage?"

- It is very hard to achieve high uptime
- People do not notice the stops that add up the most: the very short ones
- Story (on a later slide) about loop machine with three tenders
- Denso rules for line workers repairing their own machine
  - you have 30 minutes to fix it yourself
  - if you don't think you can fix it or if 30 min are up, call the repair crew

Histogram of Stoppage Durations

Image removed for copyright reasons.
Source:
Figure 16-3 in [Whitney 2004] Whitney, D. E. *Mechanical Assemblies: Their Design, Manufacture, and Role in Product Development.* New York, NY: Oxford University Press, 2004. ISBN: 0195157826.

Where Do All The Seconds Go?

W. M. Chow, Assembly Line Design, Marcel Dekker, 1990

24 hours per day

Scheduled operating time (utilization)

Unscheduled (bad) downtime
- part jams
- queue block/starve
- machine broken

Scheduled (good) downtime
- tool change
- variety change
- preventive maintenance
- employee breaks

Process efficiency
- task time variation, line balance, logistics, scheduling

Process quality
- % bad parts or cycles
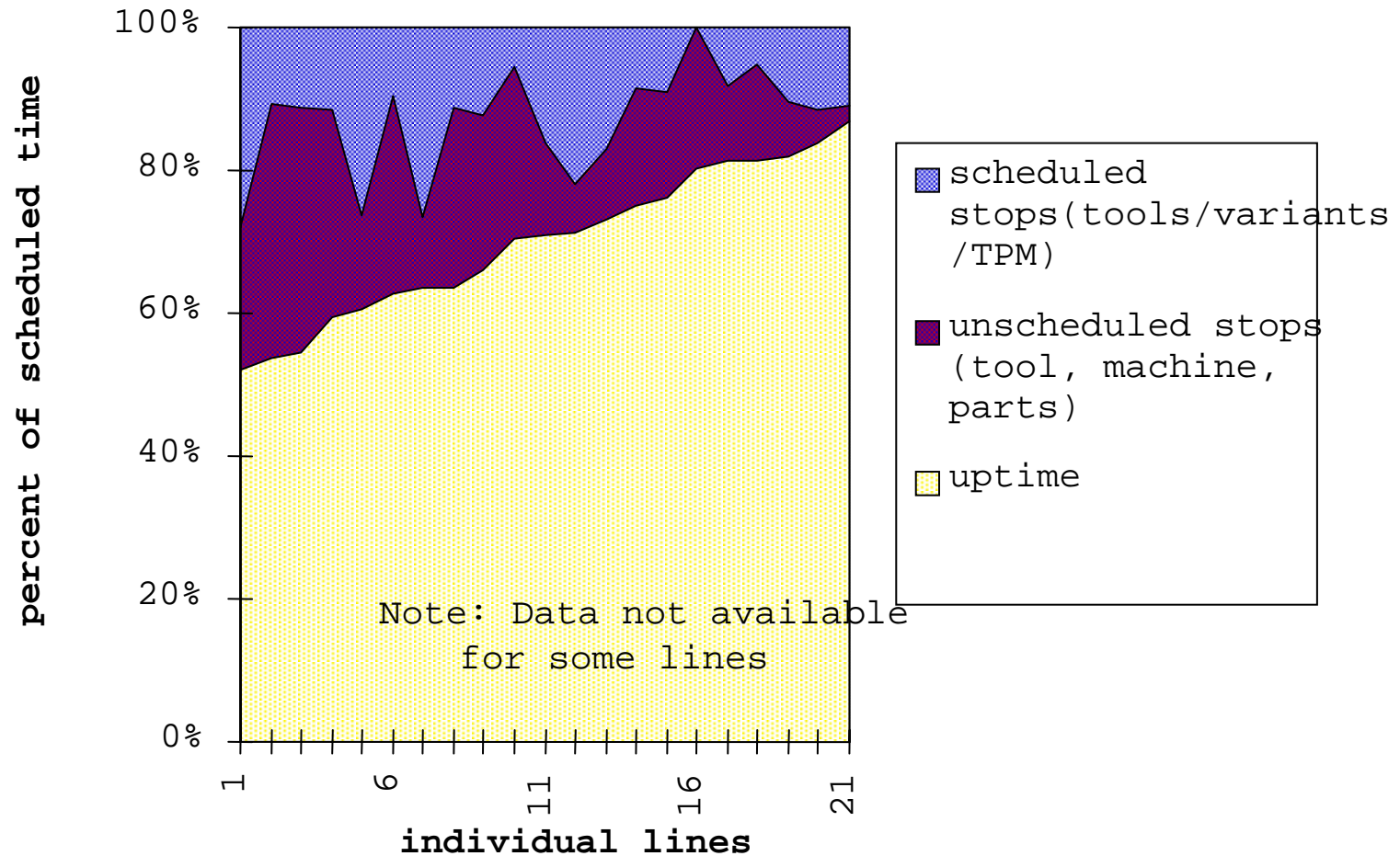
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Figure 16-2 in [Whitney 2004] Whitney, D. E.
Mechanical Assemblies: Their Design, Manufacture, and Role in Product Development.
New York, NY: Oxford University Press, 2004. ISBN: 0195157826.

Block Line Uptime Varies Greatly from Plant to Plant

Chart: percent of scheduled time (y-axis, 0% to 100%) vs individual lines (x-axis, 1 to 21)

Legend:
- scheduled stops(tools/variants /TPM)
- unscheduled stops (tool, machine, parts)
- uptime

Note: Data not available for some lines

Uptime Is a Property of the Engine Plant

Uptime Values Provided by Engine Plants

Note that on Average, in one Plant, there is less than a 15% Difference in Uptime between any of the 3 Machining Lines

Legend:
- Uptime BLOCK
- Uptime CRANK
- Uptime HEAD

Engine Plants
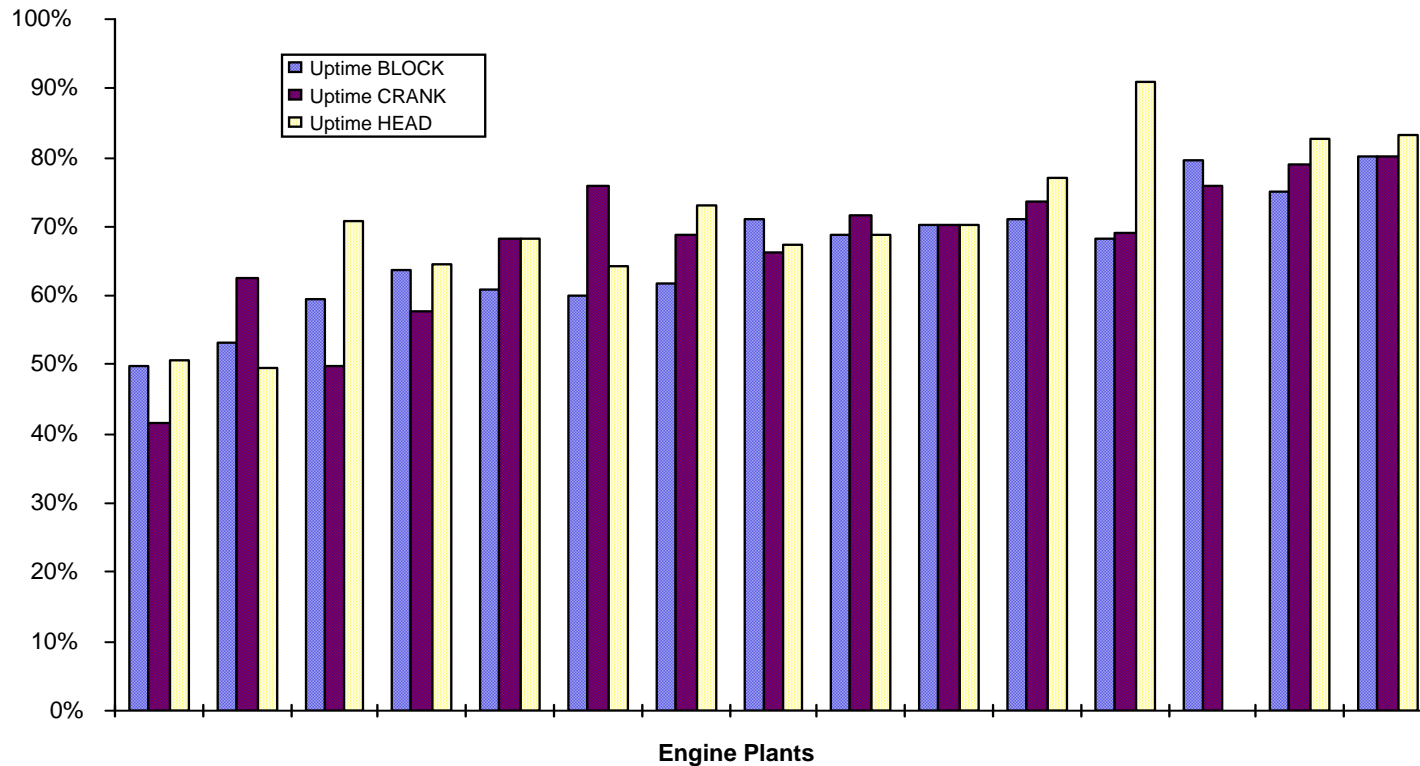
How to Get 85% Uptime

- Loop-style assembly machine for washing machine feet

- Two people with wands to beat stuck part feeder tracks

- Machine with bus-style pull cord

- When a track jams, the people whack at it with their wands and yank the cord to restart the machine

- Result is 85% uptime

Basics of Simulation

- Allows for inclusion of a variety of random events
  - machine stoppages
  - queue blockages and starvation
  - absence of workers, pallets, parts, fixtures
  - resource contention and levels of service
  - queue capacity
- Companies are surprisingly unaware of the effects of random events and do not take good data on downtime
- "We made the line 'lean.' It had no buffers. It didn't work."

Simulation

- Uses a system definition to run a time-based simulation

- Often includes random variables

- Can be "continuous" time or discrete event

Continuous and Discrete

- Continuous means equal size time steps
- Discrete event means that time advances until the next event can occur
  - time steps during which nothing happens are skipped
  - duration of activities determines how much the clock advances

Components of a D. E. Simulation

- Simulations contain
  - *activities* where things happen to entities during some time (which may be governed by a probability distribution)
  - *queues* where entities wait an undetermined time
  - *entities* that wait in queues or get acted on in activities
    - entities can have *attributes* like kind, weight, due date, priority

Things that Can Be Simulated

- Factories
  - entities are products, people, transporters, tools
  - activities are machines for fab or assembly
  - queues are conveyors, warehouses
- Highways
  - entities are cars, trucks, cops
  - activities are go, stop, rage
  - queues are highways, on-ramps, off-ramps, rest stops

Goals of System Simulation

- Check the design of the system
  - Material flows - are there bottlenecks?
  - Queue locations and sizes - do they get blocked or starved?
  - Resources - are they sufficient, do they starve important operations?
  - Failure modes - what are they and what causes them?
- Check if it has the required capacity
- See what different types of downtime do to performance
- Improve the design

Choices for Probability Distributions

- Things that have distributions:
  - Station operating times
  - Breakdown intervals
  - Station repair times
  - Transport system performance
- Alternate distributions
  - Normal
  - Weibull
  - Uniform
  - Fatigue Life
  - Rayleigh

Station Time Data

- Obtained by Prof Tim Baines, Cranfield U, UK
- Taken at engine dressing line at UK car company
- Electronic data gathered from operator's release of pallet to next station
- Averaged over many operators at many stations on this line to protect anonymity
- Main conclusion is that times vary much more widely than is accounted for in typical simulations
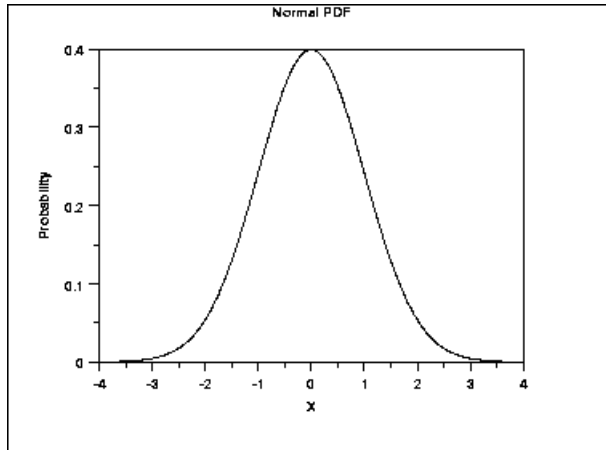
Activity Time: a typical day

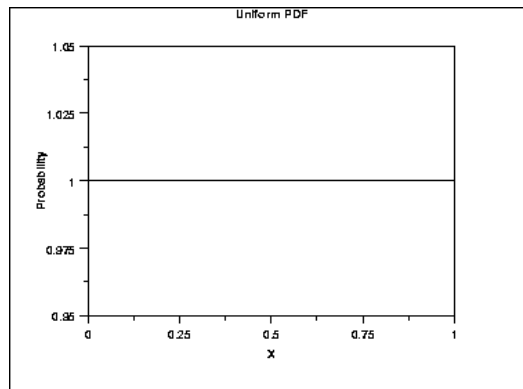Graph removed due to copyright restrictions. (Workstation time [s] vs Time of Day.)

Activity Times & Production Standard Times (PST)

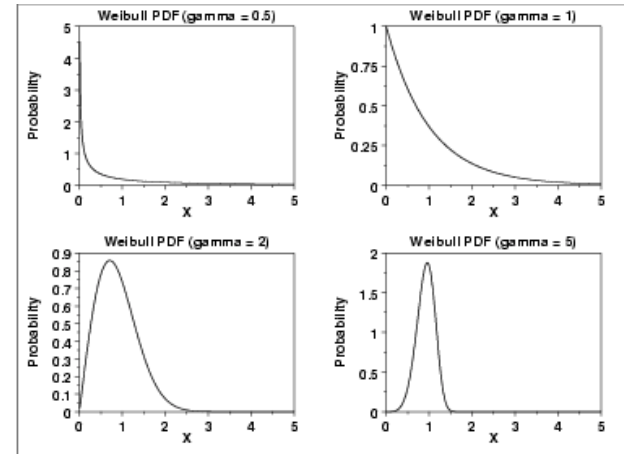Graph removed due to copyright restrictions. (Frequency vs Activity Time.)
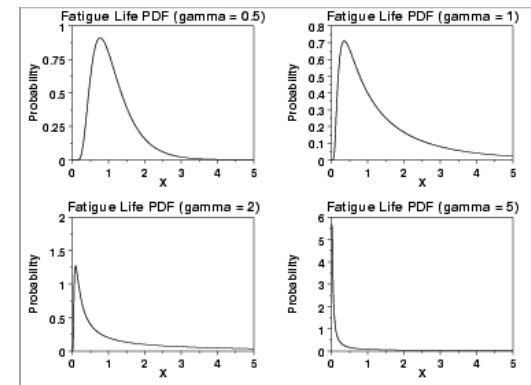
Common Probability Distributions

Normal

Weibull


Uniform

Fatigue Life

http://www.itl.nist.gov/div898/handbook/eda/section3/eda366.htm

Kinds of Design Choices

- Number and location of resources
  - People - operators and repair crews
  - Machines
  - Pallets and their carrying capacity
  - Tools
- Queue locations, sizes, disciplines
- Priorities of activities that compete for limited resources
- Floor layout – distances, separation of people and machines
- Kinds of transport – conveyors, AGVs
- Assembly sequences

Simple Simulation Diagram
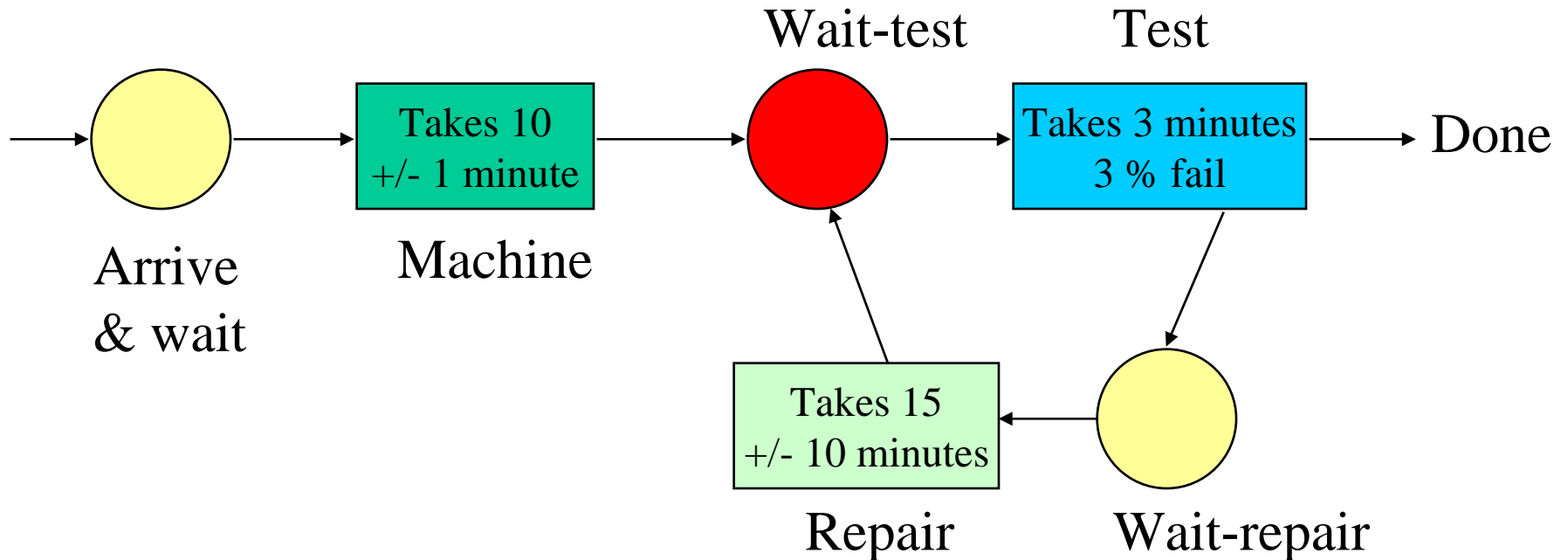
Note: If Wait-repair and Wait-test both are full, the system will become deadlocked as soon as the next unit needs repair because the test station will be unable to unload and take the next unit.

What You Might Learn

- Products fail too often

- Repair takes too long

- A queue is so short that it fills up and prevents products from moving along

- Machines break too often, or there are not enough repair personnel, or it takes them too long for them arrive, etc

- Then you have to do something about it

How a Sim Works

- Scan the agenda of activities
- Find the first ones that can execute (or continue executing)
  - all the entities they need are available
- Advance the clock to the end of the activity with the shortest operating time
- Send its entities to their destination queues
  - the destinations must be open, not full
- Go back to the top

Basic Modeling Considerations

- Identify all the elements and activities
- Decide which activities need which entities
- Separate the activities with queues
- Decide the queue discipline
  - first come first served, latest, heaviest, etc
- Decide where entities should go when the activity is finished
- Often, when you have done all this, you have learned so much that you do not need to run the simulation

Bottlenecks

- Every system has a bottleneck
- It's the station with the minimum capacity, the one that paces the system's operations (often the one with the longest operation time)
- A cycle lost on the bottleneck station is a cycle lost forever
  – see *The Goal* by Goldratt
- Queues at non-bottleneck stations are illusions

Strengths and Weaknesses

- Modeling makes you think

- You can run systematic experiments, even DOE

- Modeling is not a solution, just a model of a proposed design

- GIGO applies

- The probability distributions you choose may not be the correct ones

Conclusions

- Simulation is valuable and should be part of every manufacturing system design process

- Simulation makes you think about a stochastic world, which is reality

- Too often, simulation is done only when a problem is discovered with a system that is already installed and hard to change

- In this and other ways, simulation is like variation analysis