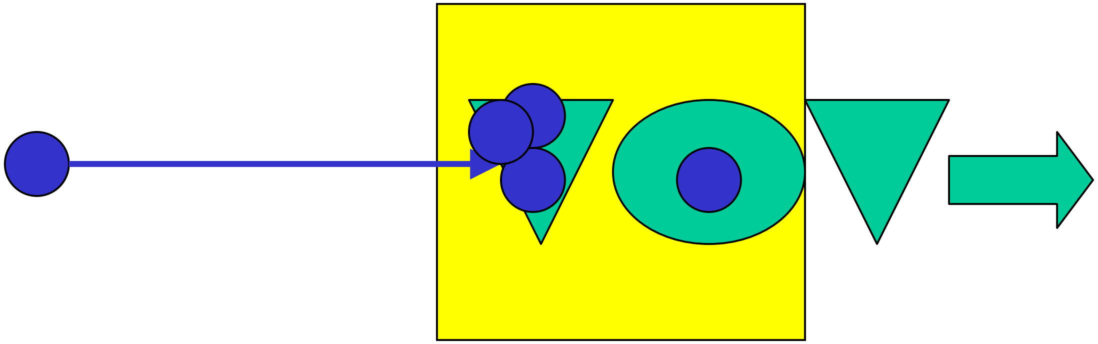
Flow Time & Capacity Analysis

Process Flow Measurement

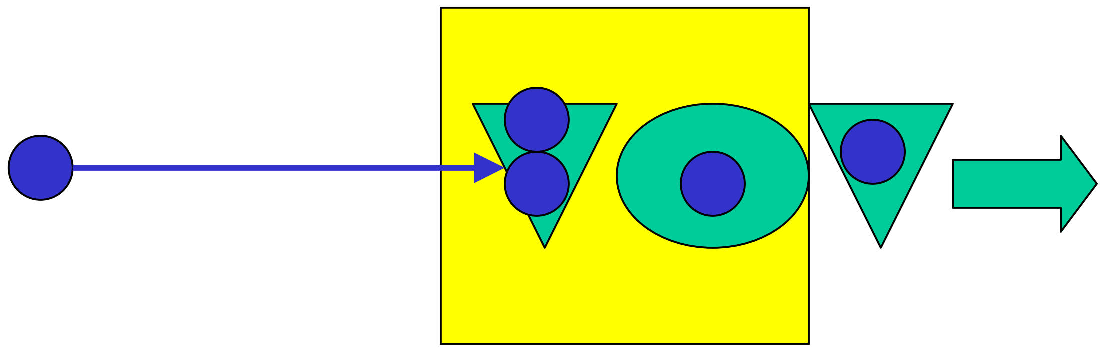
- Process boundaries
- Process flow rate, in and out R [#/T]
- Process inventory I [#]
- Unit flow time T [T]

Suppose we observe a grinder



What do we actually observe?

We can observe:



Arrival Process

Events:

job arrives at IB

Service Process

- job leaves IB, starts operation
- job finishes operation, enters OB

job leaves OB

Averaged Over Time ...

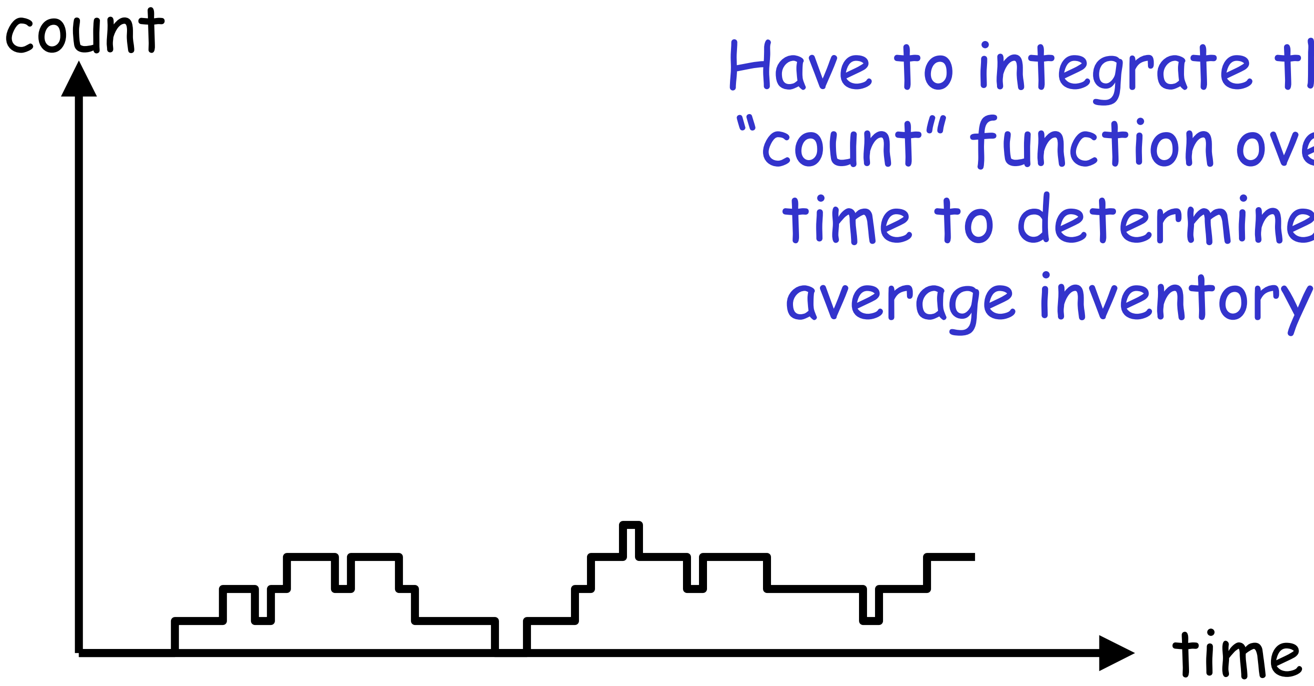
- Rate in equals rate out (or we have a problem!)
- I = R x T
- [units] = [units/time] x [time]

Fundamental Law of Flow
"Little's Law" after John D.C. Little

Observations for Little's Law

- Observe arrivals (time stamp, count number per unit time)
- Observe processing (time stamp process start/end, compute process duration, compute waiting time, add to get time in system, average over jobs)
- *How do we determine inventory?*

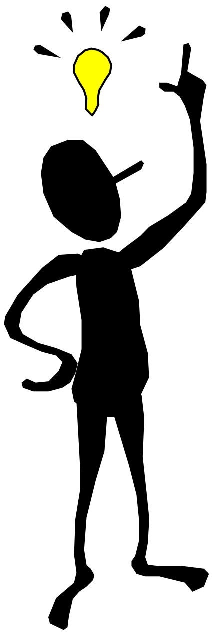
Inventory



Have to integrate the "count" function over time to determine average inventory

It's usually easier to determine R and T, and compute I!

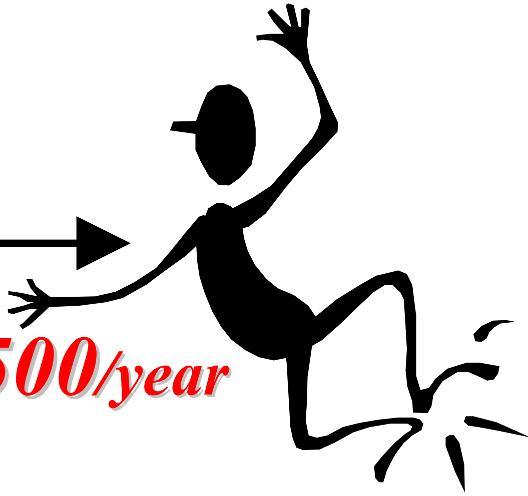
I = R x T at Georgia Tech



12,500 Students

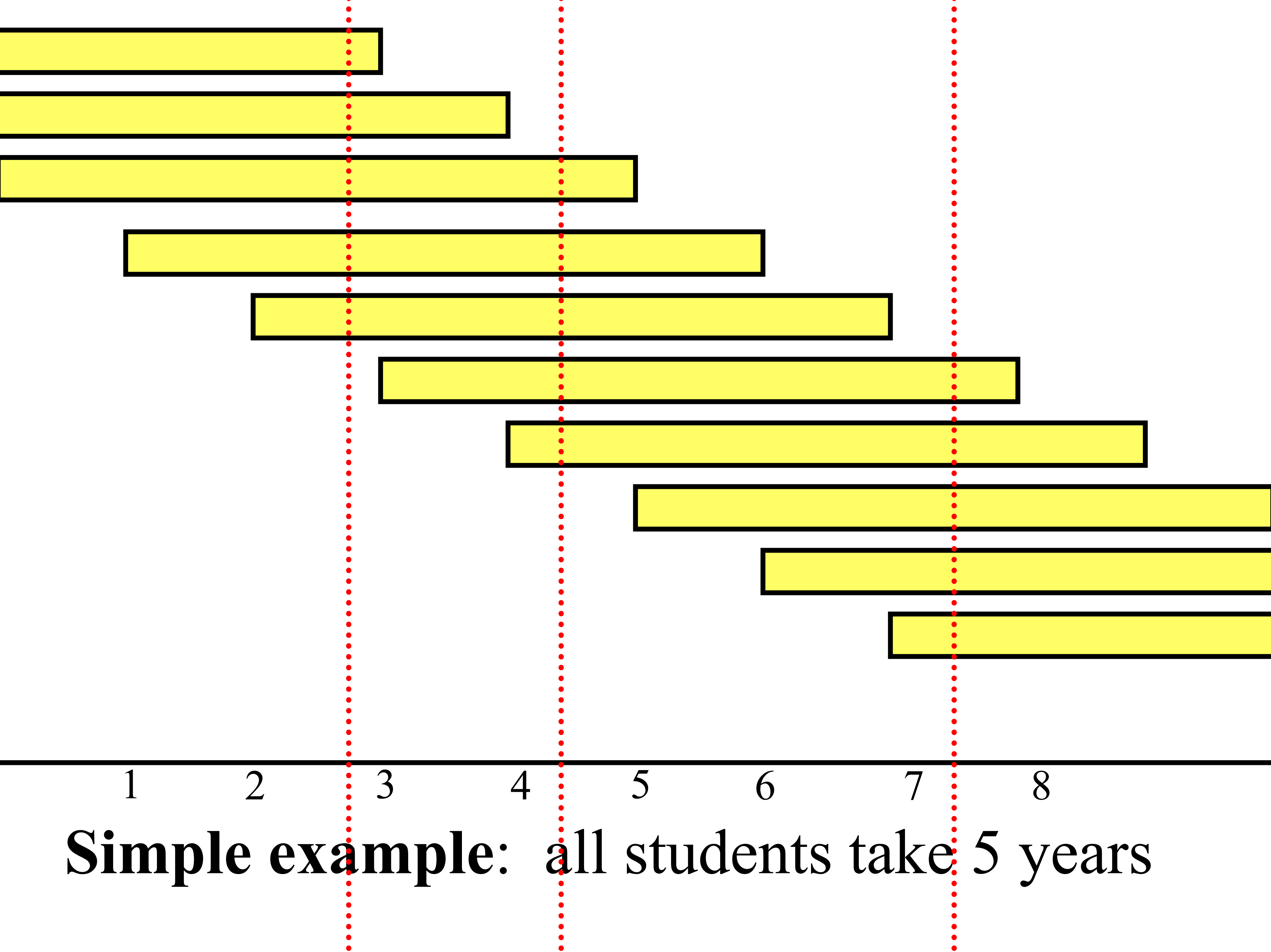
Georgia Tech

2500/year



Ignore "losses" in the process!

How long does it take to graduate?



Simple example: all students take 5 years

Measuring Complex Flows

- Section 3.6.6
  - Measures at each individual process
  - Measures for each flow among processes
  - Weighted average over flow types

How Many Processes?

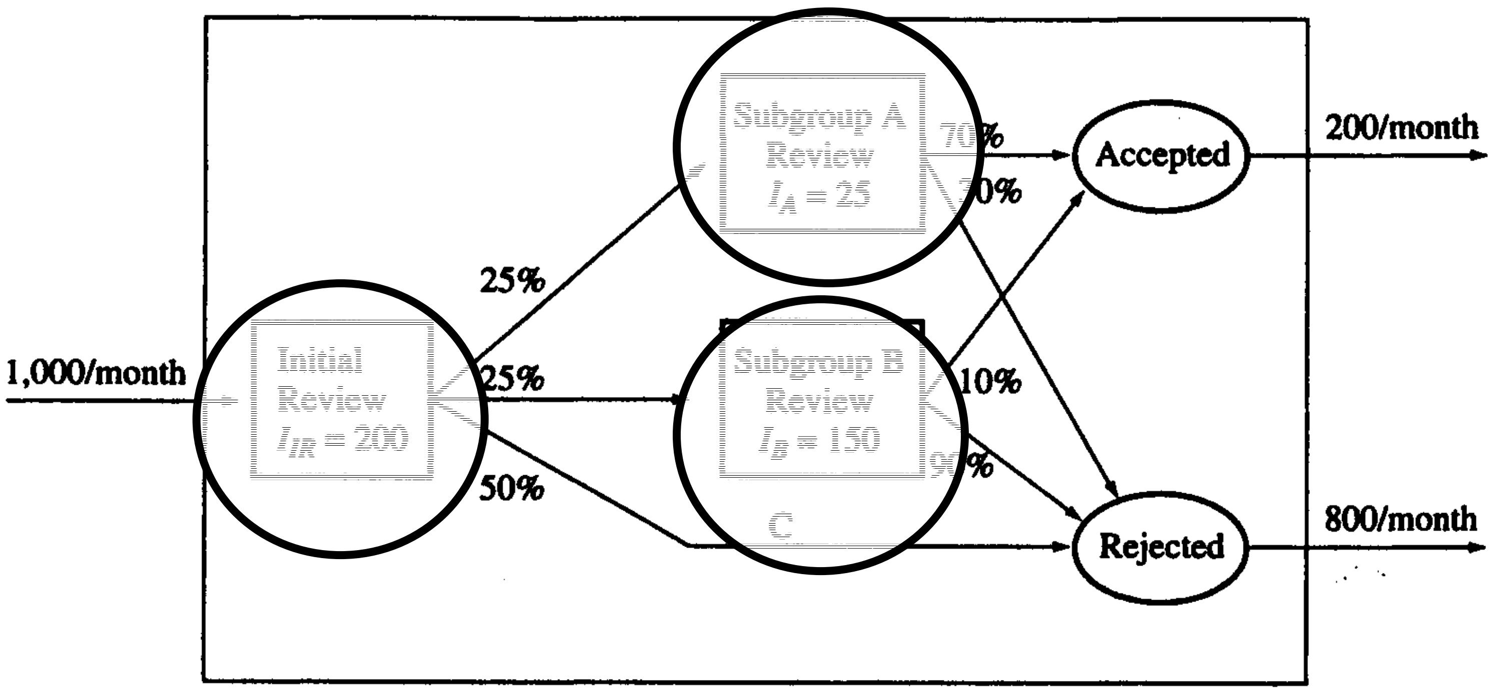


FIGURE 3.3 Flow Chart on MBPF Finance Process II

I = R x T *at each (sub)process*

How Many Flow Patterns?

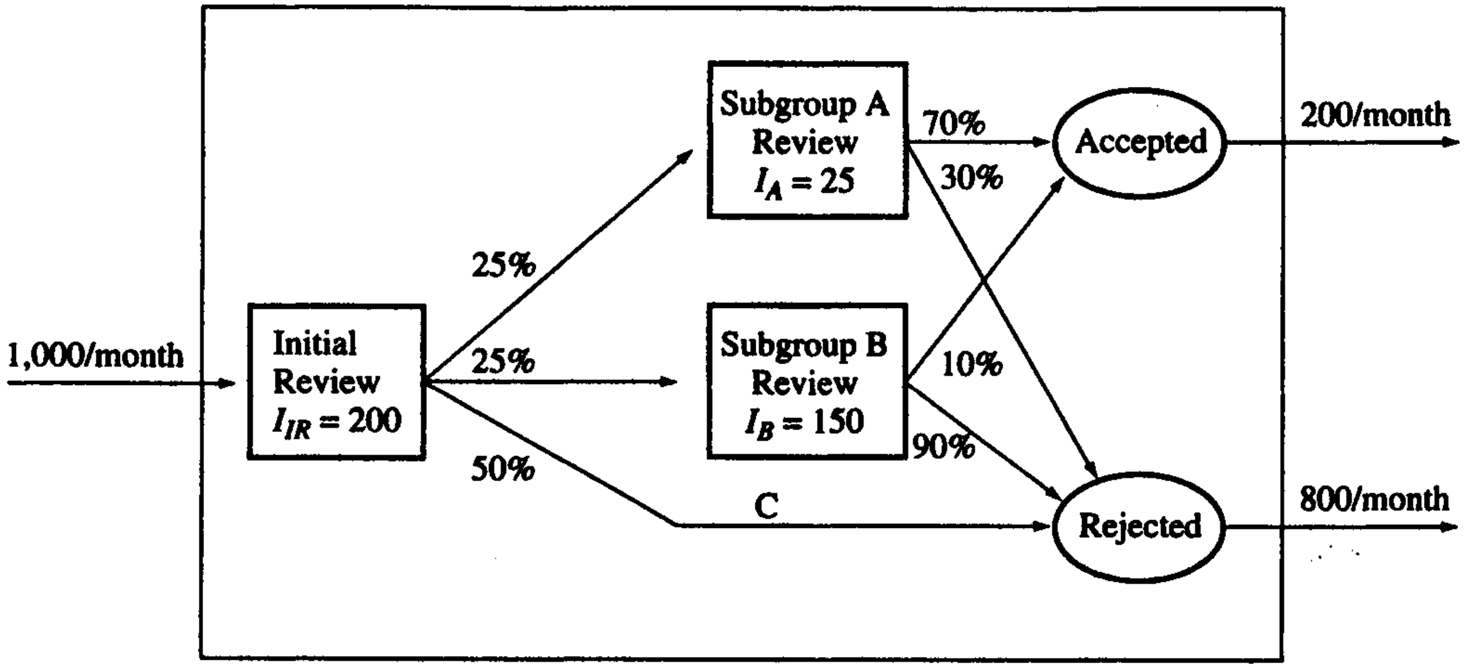


FIGURE 3.3 Flow Chart on MBPF Finance Process II

For each pattern, total T is sum of T at each process

T for each individual process

- IR: $200 = 1000T_{IR}$
- A: $25 = 1000(.25)T_A$
- B: $150 = 1000(.25)T_B$

For the System

- System avg I = sum of process avg
  = 200 + 25 + 150 = 375
- System avg T = weighted avg process flow T
  $= [250(T_{IR} + T_A) + 250\,(T_{IR} + T_B) + 500T_{IR}]/1000$
- Also, 375 = 1000T

Flow Unit Issues

- I = R x T applies to flow units
- How are flow units defined?
  - Conservation principle
  - Operations indicator principle
- Insure consistency of definitions!

Conservation Principle

- Matter is conserved!
- Weight in = weight out, on the average

Operation Indicator Principle

- We may want to define flow units so they correspond to execution of operations
  - piece: milling operation performed on individual pieces
  - container: cleaning, deburring, transport operations performed on all parts in a container
  - ***Job***: we use standards to determine op'n time
- Conversion factors:
  - p [pounds/piece]   c [piece/container]

Example 4.2

- Suggests scaling flow units; rate is described in "equivalent standard units" rather than in "pieces"
- This really makes sense ONLY if the different models scale the same for all important criteria, e.g., m/c time, labor hours, cost, etc. (which is unlikely)
- Since $I = R \times T$, if we scale R, then we also scale I; T has units of [time] so it is NOT scaled.

Using Little's Law

- Given two of (I,R,T), you can determine the third.
- Given two of (I,R,T) for n-1 subsystems, and two of (I,R,T) for the system as a whole, you can determine I, R, and T for the nth subsystem.

Warning! Transition Ahead!

What about resource requirements? How much capacity is "required"?

Resource Consumption Issues

- Must be able to correlate units of flow through processes to the consumption of process resources
  - focus on machine (or tool) and people (labor) resources
  - How much of each resource is required for each operation
- May require detailed analysis of how operations are (should be) performed

Estimating Capacity Requirements

Operation capacity required =

R x (resource/flowunit) / utilization

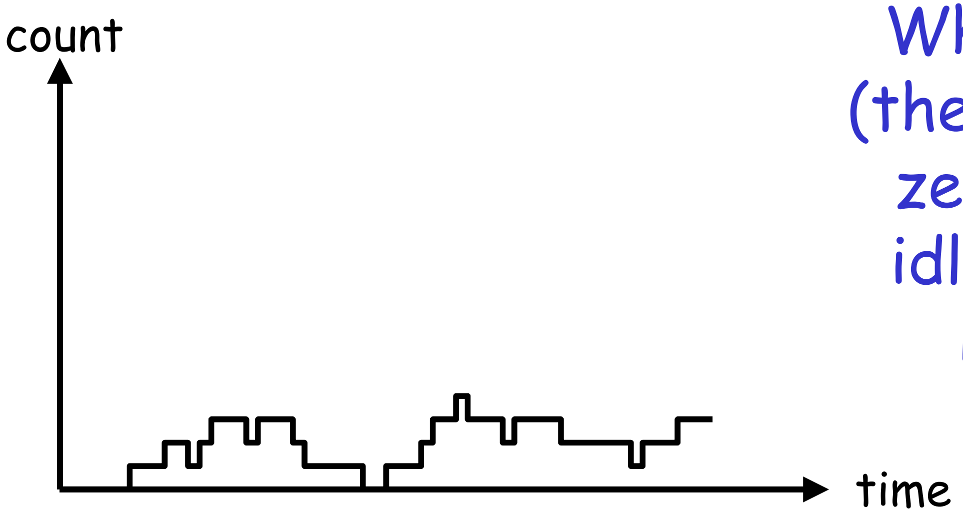
Example:

Labor hours req'd =

200 pc/day x .25 hrs/pc = 50 hrs/day

or 7.14 workers *at 100% utilization*

But utilization isn't 100%!



Whenever the count (the inventory) goes to zero, the process is idle, so utilization is less than 100%.

Estimating Capacity Requirements

Operation capacity required =

R x (resource/flowunit) / utilization

Example:

Suppose utilization is 75% (45 min/hour)

Labor hours req'd =

200 pc/day x .25 hrs/pc / 0.75 =

50 hrs/day / 0.75 = 66.67 hrs/day

or 9.52 workers

Warning! Transition Ahead!

Look at a "network" of processes, but instead of applying I=RT, we are going to look at <u>theoretical</u> MCT.

Process Flow Graphs

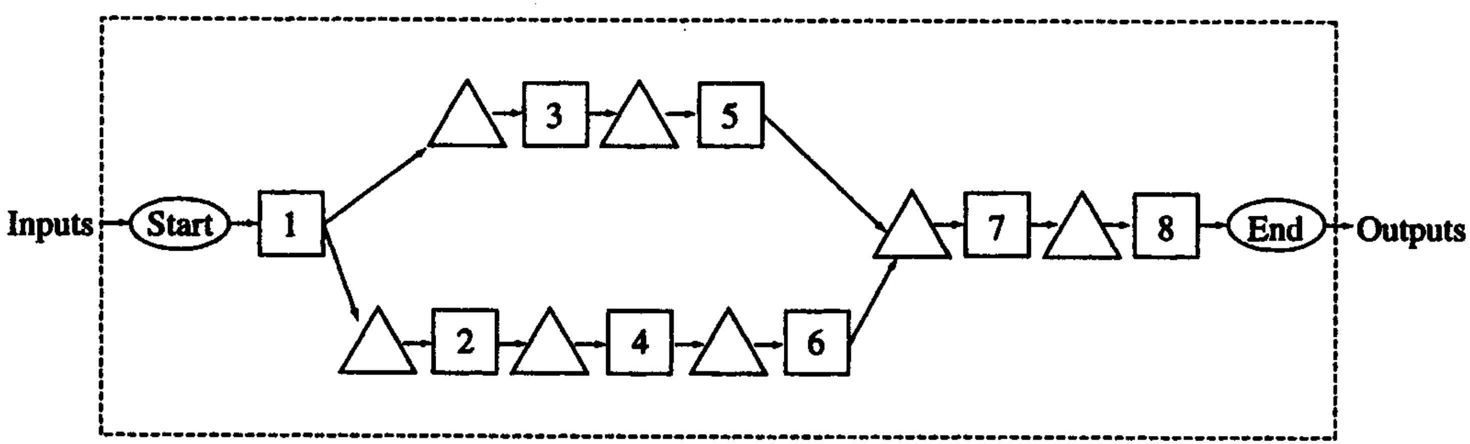


FIGURE 4.1 Process Flow Chart for MBPF, Inc.

We will refer to this as a process flow *graph* rather than a process flow *chart*, because this shows only the structure of the flows, and not the detailed operation information.

Operation	Details of Operation Present Proposed	Operation	Transport	Inspection	Delay	Storage	Distance (ft)	Quantity	Time	Notes
1	Separate								10	Create two flow units
	Transport base							1		Subpath for base flow unit
	Base punch buffer									
2	Punch the Base							1	30	
	Transport base							1		
	Base form buffer									
4	Form the Base							1	6	
	Transport base							1		
	Base subassemble buffer									
6	Subassemble Base							1	13	
	Transport to Assemble buffer							1		End subpath for base flow unit
	Transport Roof							1		Subpath for roof flow unit
	Roof punch buffer									
3	Punch roof							1	22	
	Tranport roof							1		
	Roof form buffer									
5	Form roof							1	12	
	Transport to Assemble buffer							1		End subpath for roof flow unit
	Assemble Buffer									
7	Assemble							1	10	
	Transport to Inspect							1		
	Inspect Buffer									
8	Inspect							1	36	

Using Both Tools

- Process flow graph to “map” the actual path of flow units through processes, and document resource usage
- Process flow chart to document times and distances, and identify unquantified delays

Improving Flow Time Efficiency

- Key concepts:
  - process flow graph
  - process flow chart
  - critical path

Concept of Critical Path

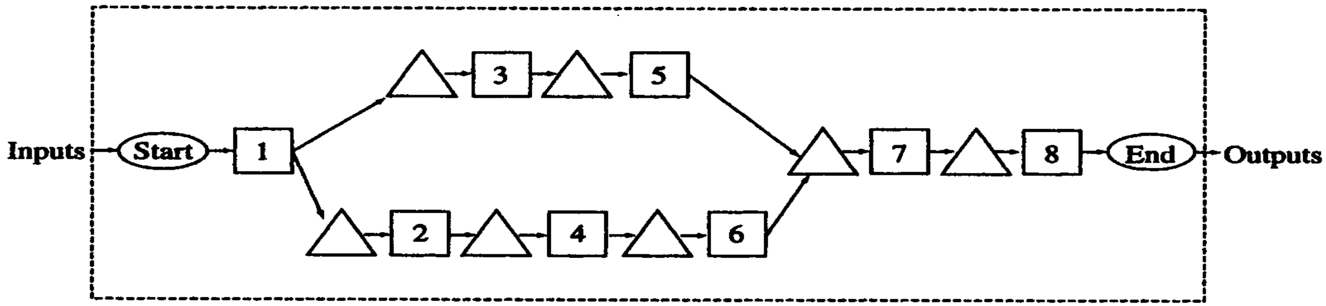


FIGURE 4.1 Process Flow Chart for MBPF, Inc.

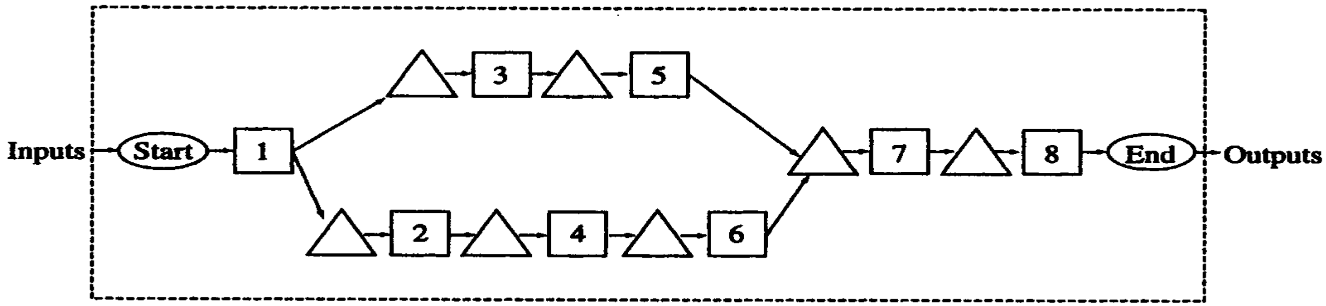
TABLE 4.2 Activity Times and Work Content for MBPF Inc.

	Activity	*Activity Time (Minutes)*	*Number of Visits*	*Work Content*
1	Separate	10	1	10
2	Punch the base	25	1.2	30
3	Punch the roof	20	1.1	22
4	Form the base	5	1.2	6
5	Form the roof	10	1.2	12
6	Subassemble	10	1.3	13
7	Assemble	10	1	10
8	Inspect	30	1.2	36

What is the MCT?

- Calculate the longest path in the process flow graph
- The longest path is also called the *critical path*

Concept of Critical Path



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8	Inspect	30	1.2	36

Flow Time Efficiency

- Sum of quantified process times on the longest path is the ***theoretical flow time***, T* *(rework issue…)*
- Actual flow time, T, is never *less* than T*
- Flow time efficiency is $T^*/T \leq 1.0$
- All other things being equal, a larger flow time *efficiency* is preferred.
- Sometimes the inverse of flow time efficiency is called the "x factor"

What causes $T > T^*$?

Improving Flow Time

- Focus on critical path--make T* smaller
- Reduce work content of operations on the critical path
- Move operations off the critical path

Reducing Work Content

- Improve process to increase rate
- Reduce or eliminate NVA steps, e.g., increase lot size to reduce the number of setups
- Reduce product rework
- Reduce or eliminate inspections

Moving Operations

- To a non-critical path in the process flow graph
- To a pre-processing or post-processing step that is off the process flow graph

Dilbert Observation

- If you are evaluated on the basis of flow time efficiency, i.e., T*/T, one way to make your efficiency better is to *increase* T* while holding T constant.
- Is this really a good idea for the organization?

Warning! Transition Ahead!

Instead of looking at MCT, what about the maximum *rate* at which units can be produced?

What's the maximum R?

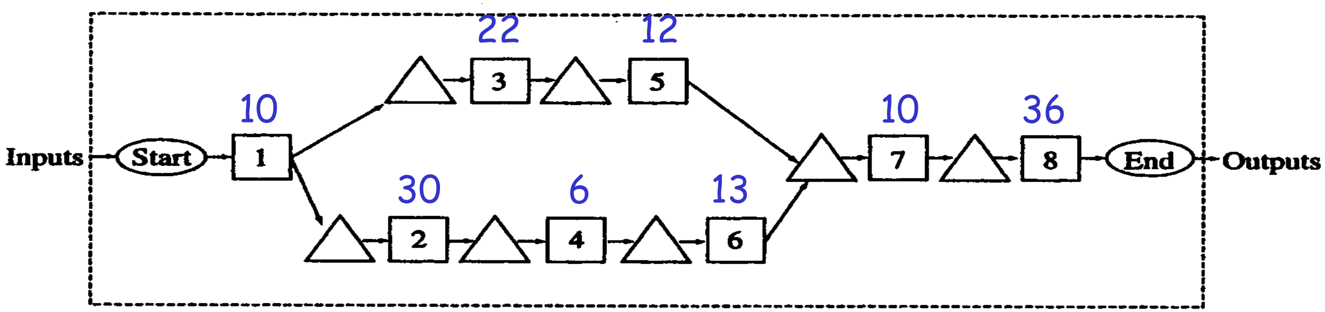

FIGURE 4.1 Process Flow Chart for MBPF, Inc.

it's the maximum possible for any one of the processes in the process flow graph--so the *slowest* process determines the limit for R

Summary

- I= R x T for complex flows
- Process flow graphs and charts
- Flow unit dimensions & conversion factors
- Scaling in I = R x T
- Capacity req't estimation
- MCT
- Rate