

A firm supply's goods and/or service to fulfill customer/market demand

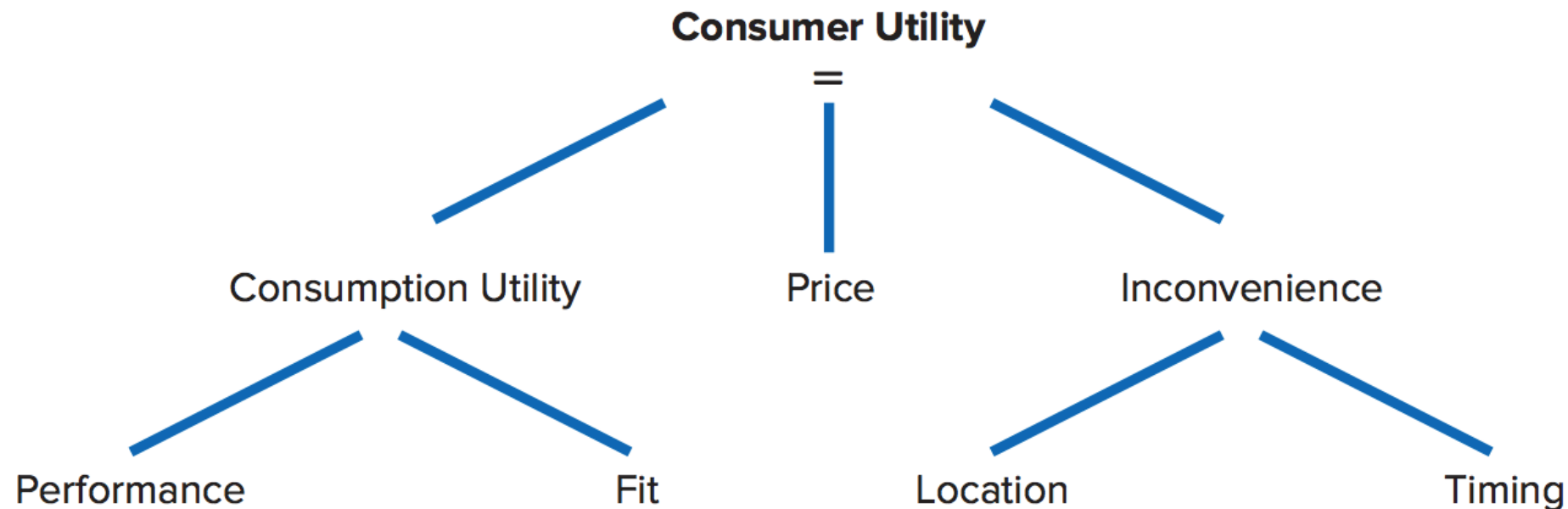


*Matching supply with demand is the goal of **Operations Management***

What Defines a “Good” Process?

Ultimately, all organizations compete on **delivered value**

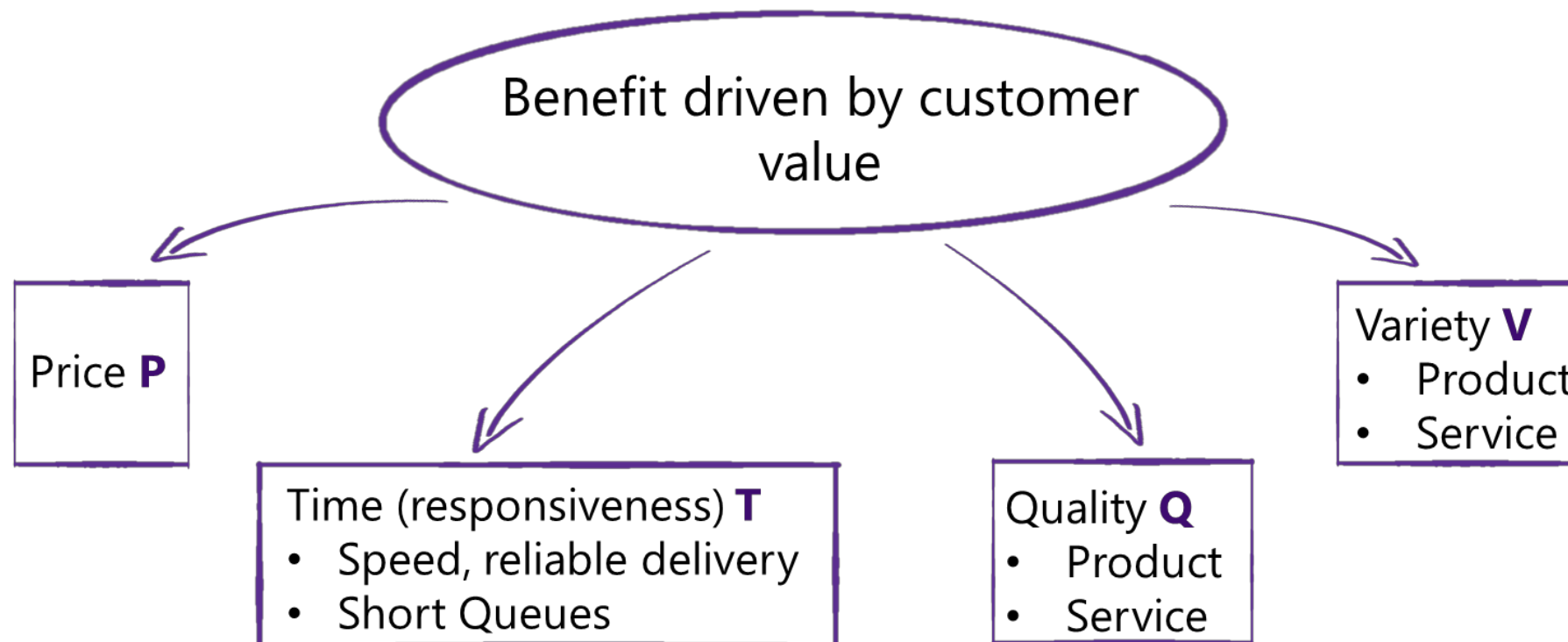
*Delivered value of a process =
benefit driven by customer value – total process cost*



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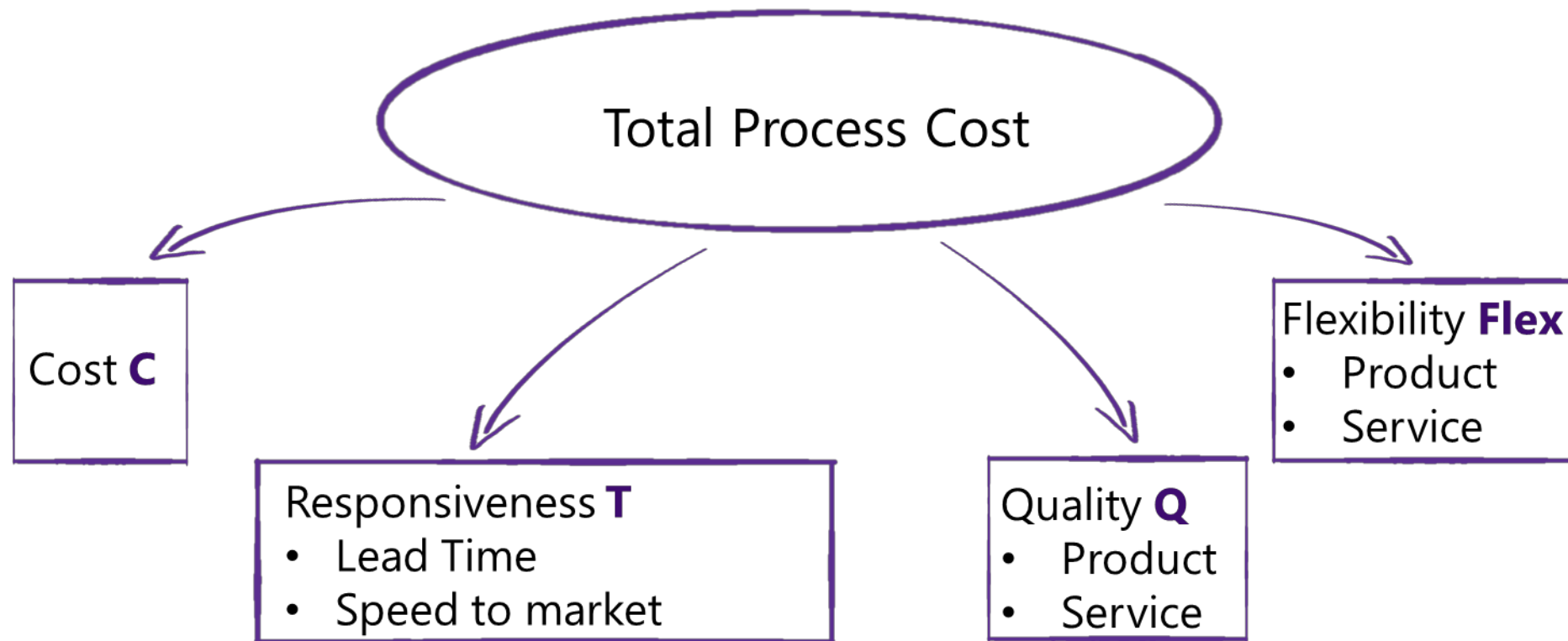
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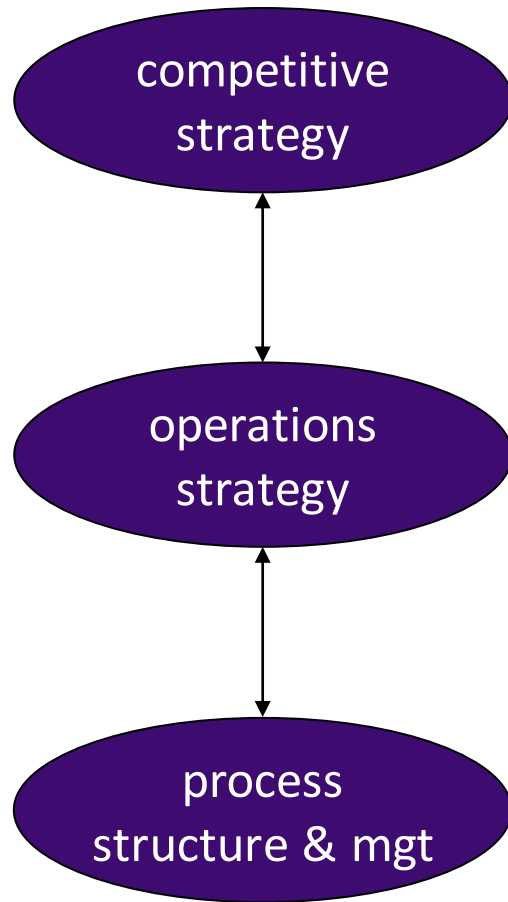
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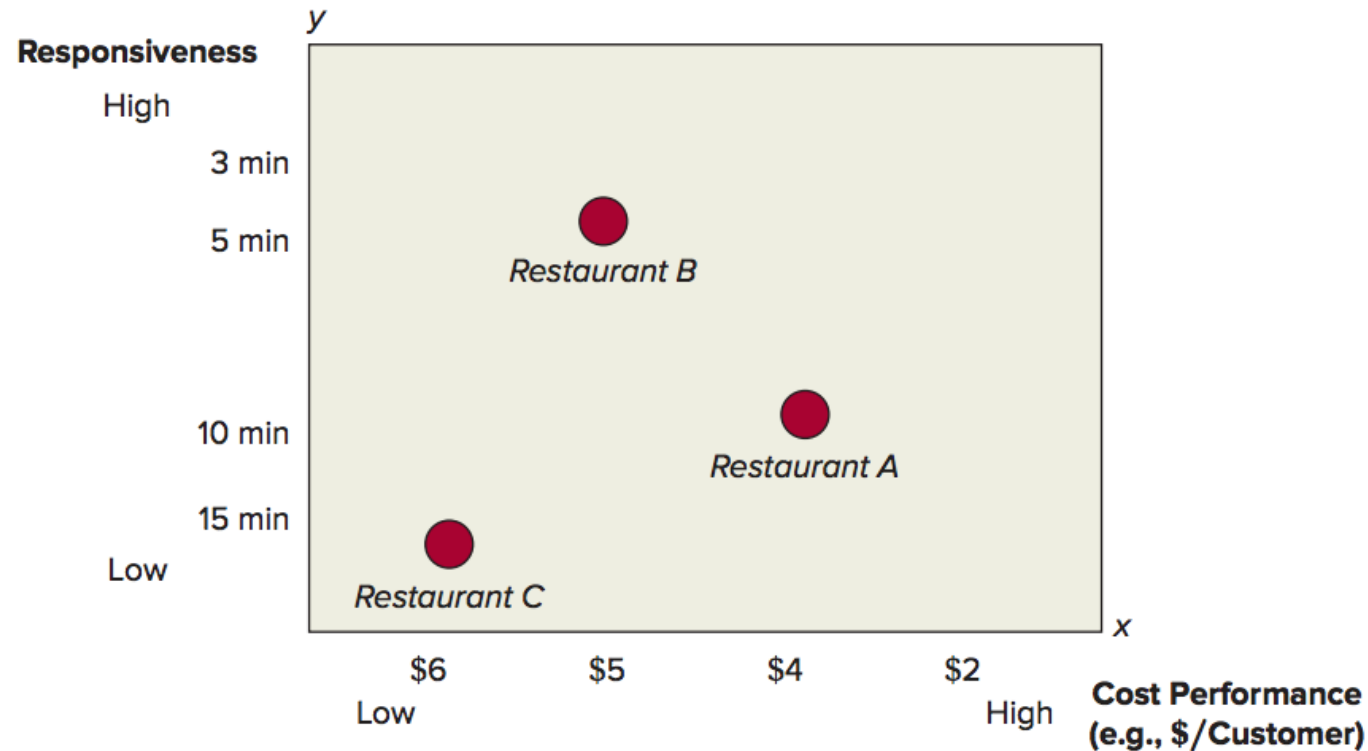


A Strategic Framework for Process Design and Improvement



1. What is our strategic position: how do we compete & provide value in the market?
 - What is the value proposition to our customers?
 - **Rank (*Price, Time, Quality, Variety*)**
2. Given our strategic position, what must operations do particularly well?
 - Which *competencies/capabilities* must ops develop?
 - **Rank (*Cost, Time, Quality, Flexibility*)**
3. Given needed competencies, how should operations processes be structured to develop competencies/capabilities that support strategy?
 - **Process choice (structure) and management**

Consider a third restaurant C



Pareto dominated – A firm's product or service is inferior to competitors on all dimensions of the customer utility function.

The Efficient Frontier (Operations Frontier)

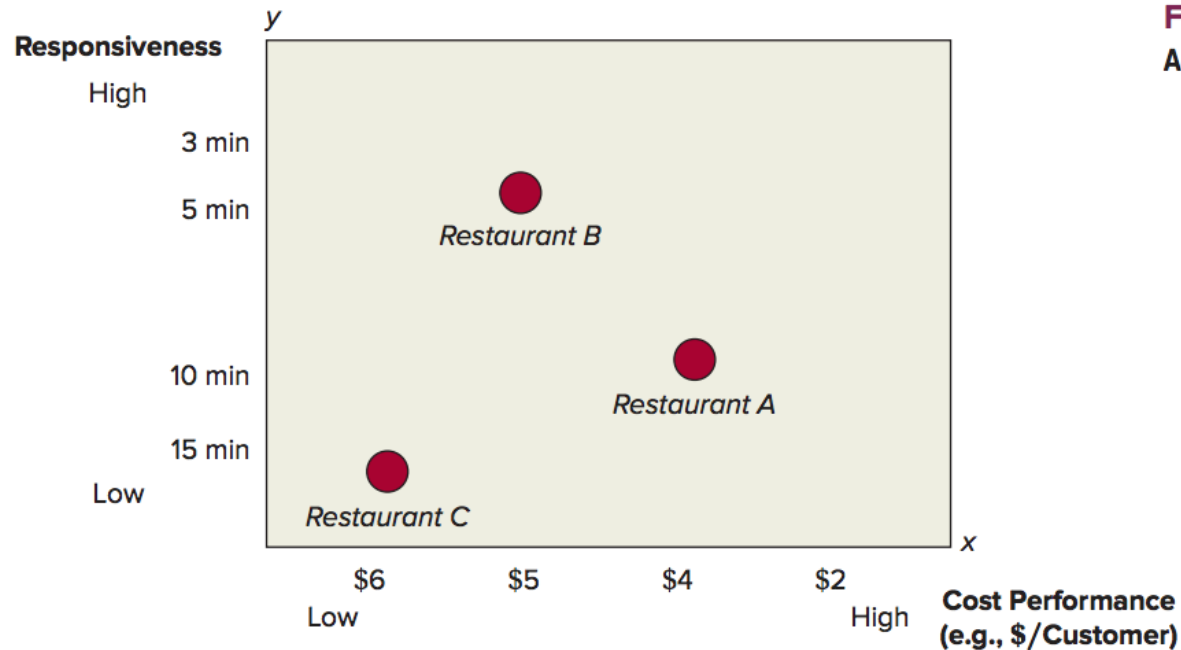


Figure 1.3

An underperforming operation (restaurant C)

Efficient Frontier:

- The set of firms that are not Pareto dominated. (Book definition)
- The minimal curve containing all current positions in an industry. (General definition)

Value of Focus

Focused Processes: focus on delivering excellent capabilities along a *limited* bundle of attributes (P, T, Q V)

- **Focused processes** are easiest to get to the “frontier”
- **Three** facts favor focused processes:
 1. A process cannot perform well on every yardstick - **Trade-offs**
 2. Simplicity and repetition breeds competence
 3. There are different dimensions for focus not only low cost

Two types of costs to consider

- **Costs for inputs:** Inputs are the things that a business purchases.
 - A fast-food restaurant must purchase meat, salad, buns, soda, etc.
 - Car manufacturers must buy steel, seats and tires.
 - Computer makers must buy displays, chips and power supplies.
 - Hospitals must purchase medications, bandages and food.
- **Costs for resources:** Resources are the things in a business that help transform input into output and thereby help provide supply for what customers demand.
 - In a fast-food restaurant, the resources are the cooking equipment, the real estate of the restaurant, and the employees.
 - Car manufacturers and computer makers have plants, warehouses, and employees.
 - Hospitals must pay for doctors, nurses, and their buildings.



Three System Inhibitors

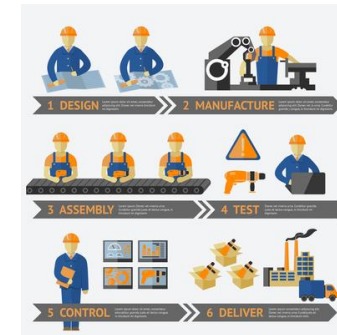
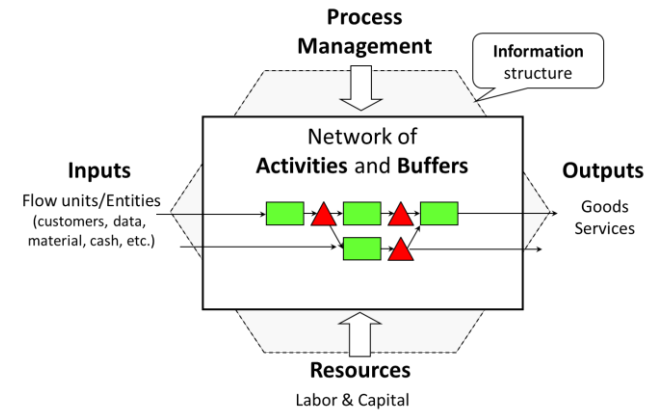
- **Waste** – The consumption of inputs and resources that do not add value to the customer.
- **Variability** – Predictable or unpredictable changes in the demand or the supply process.
- **Inflexibility** – The inability to adjust to either changes in the supply process or changes in customer demand.

What is “Good” OPS.? Summary

- “**Good**” operations maximizes delivered value, which is the difference between the benefit delivered to the customer minus total process cost
- **Value** improves when process competencies are *aligned* with targeted customer value proposition. A simple framework asks three questions:
 1. What is the value proposition to our customers?
→ Rank (*P, T, Q, V*)
 2. Given this proposition, which *competencies* must the process have?
→ Rank (*C, T, Q, Flex*)
 3. Given needed competencies, which process design is best?
→ *Build appropriate capabilities*
- How to design processes?
 - **Focused processes** are easiest to get to the “frontier”

Process view of organizations

- **Process** – A transformation of inputs into outputs through a network of activities and buffers, utilizing resources, IT and management protocols.
- **Process Scope** – The set of activities and processes included in the process. Think of this as the boundaries of the process
- **Flow Unit** – The unit of analysis that is considered in a process analysis.



Questions to ask when adopting a process view

- What are the **process boundaries**? What is the input and output?
- What is the **flow unit** or the unit of analysis?
 - “Attach yourself to the flow unit” and record its **process steps** through the process.
 - Choose a flow unit that can be used to measure and describe **all the activities** within the process.
- Who does the work? What are the **resources** for each activity?

Advantages of Adopting a Process View

- **The process view:**

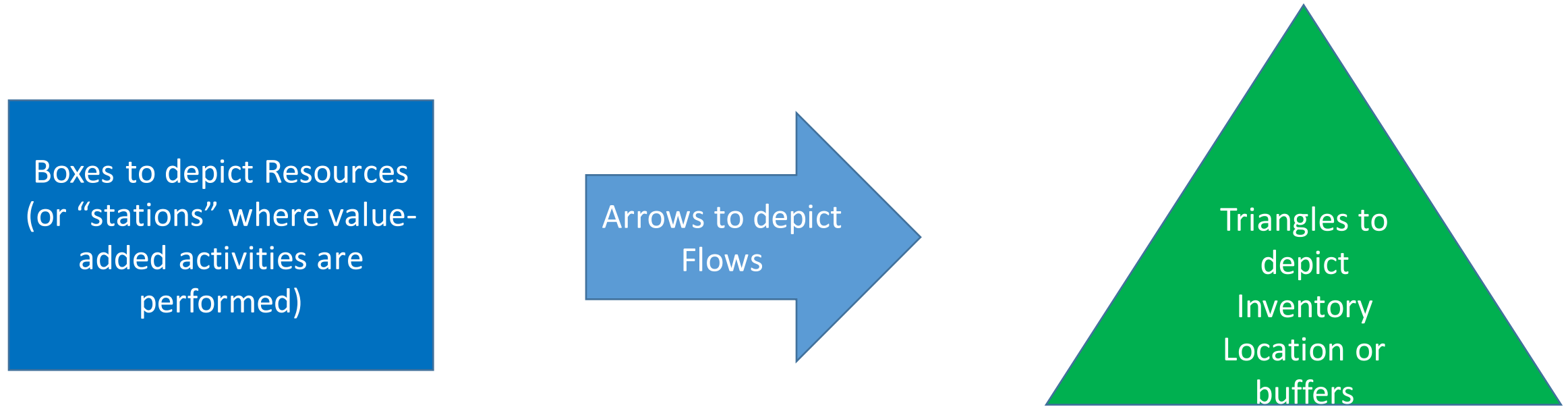
- Applies to any organization
- Applies at any level
- Cuts across functions as opposed to viewing work as aligned with functional departments

- **A focus on flows rather than snapshots**

- Rationalized management (vs. fighting fires)
- Focus on process rather than people has higher likelihood of leading to cooperation and significant improvement

The process view is a unified, customer-centric model of the organization that facilitates analysis and improvement in a systematic manner.

The Process Flow Diagram



Process flow diagram – A graphical way to describe the process. It uses boxes to depict resources, arrows to depict flows, and triangles to depict inventory location.

Resources – Workers or machines that transform inputs into outputs.

Three Key Process Metrics

1. **Inventory** – the number of flow units within a process

- Tells us how much “stuff” is in the process; takes up space and costs money
- Measured in: Flow units

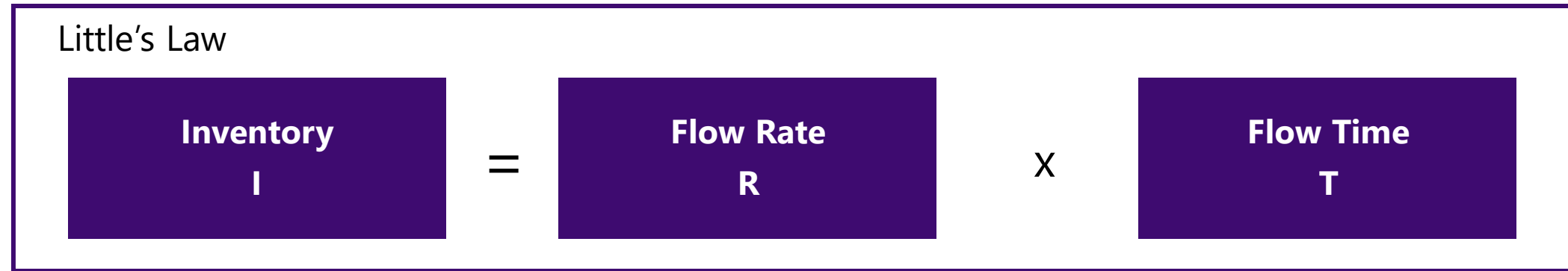
2. **Flow Rate** – the rate at which flow units travel through a process

- More units flowing through a process is generally more desirable because the point of the process is to produce output.
- Measured in: Flow units per time

3. **Flow Time** – the time a flow unit spends in a process, from start to finish

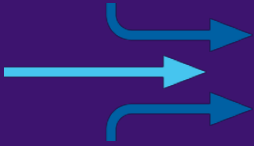
- Measured in: Time

Little's Law



If you know (or observe) any of the two key process metrics, you can use Little's Law to derive the third.

Things to remember...

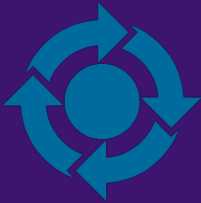


Throughput R is a **rate**, e.g. 1000 units/week.

- Requires both **physical units** and **time units**.



I , R , & T are all **long run averages**.



The unit of time in T and R must be **consistent**.

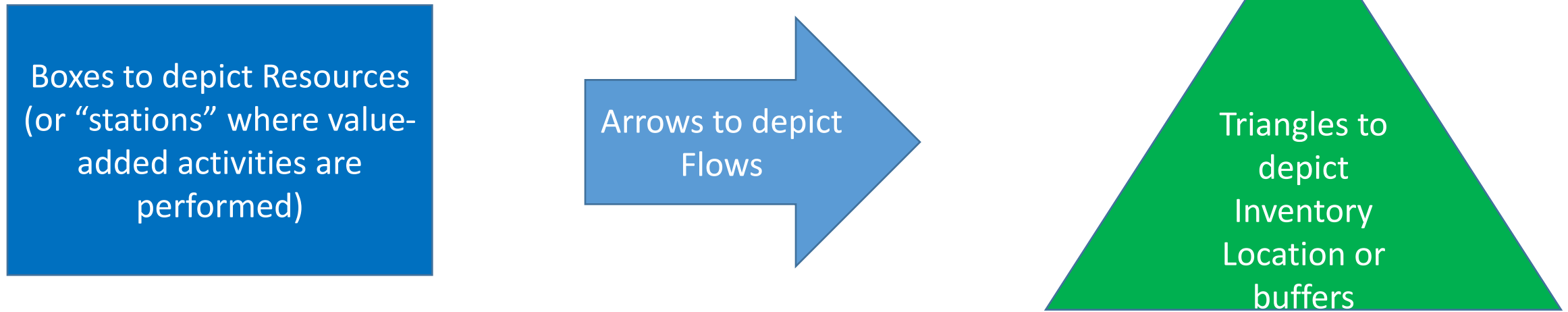
- if R is units/week then T is in weeks



The process must be **stable** (i.e., in **steady state**).

- What goes in, must go out.

The Process Flow Diagram and Process Analysis



The **process flow diagram** provides a visual chart that represents the steps of a process.

Process Analysis – a rigorous framework for understanding the detailed operations of a business

Location in a process

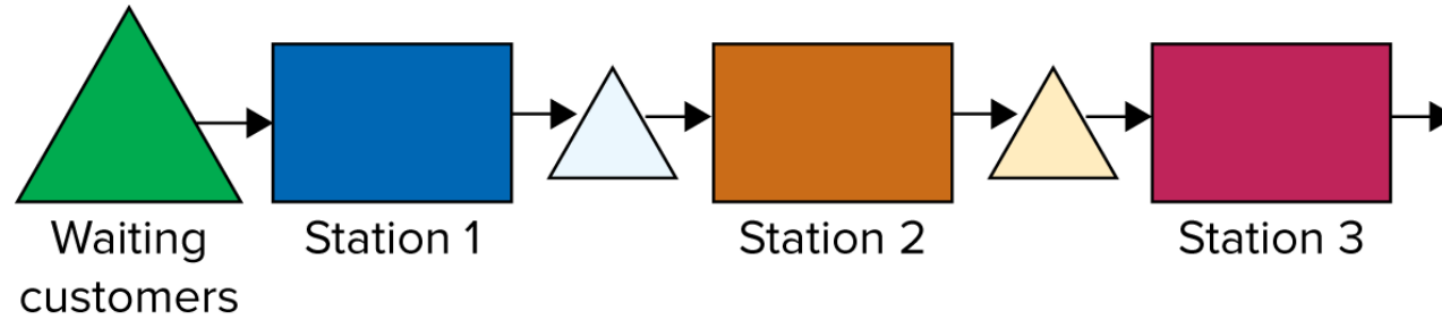


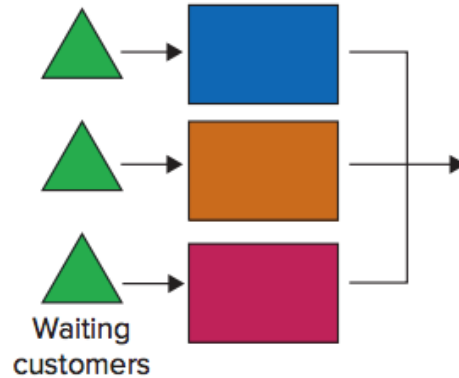
Figure 3.2 Complete process flow diagram

Upstream – the parts of the process that are at the beginning of the process flow

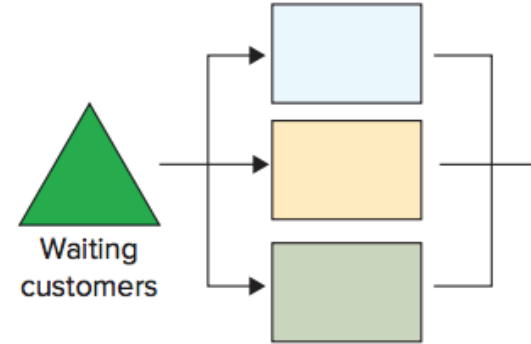
Downstream – the parts of the process that are at the end of the process flow

Alternative Process Flow Diagrams

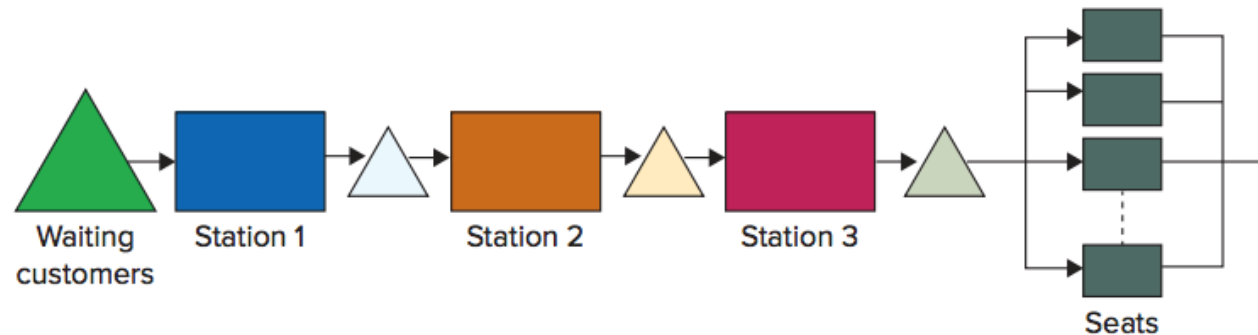
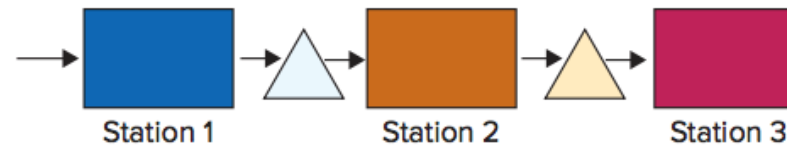
Alternative a: Three parallel processes



Alternative b: Common queue



Alternative c: No waiting



Understanding the Process

- Process flow diagrams are **flexible**, so the manager decides what aspects to study.
- Drawing the process flow diagram **should always be the first step** in process analysis.
- Many different processes to analyze
- Defining different flow units

Processing Time and Capacity: One-step-process

Processing time – The time it takes a resource to complete one flow unit

- Think in terms of averages.

Capacity – The maximum number of flow units that can flow through a resource per unit of time

TABLE 3.3 Typical Processing Times

Activity	Processing Time
Cardiac surgery (double-bypass procedure)	4 hours/patient
Installation of a rearview mirror in automotive assembly	50 seconds/vehicle
Underwriting a simple small business loan	40 minutes/loan
Simple transaction call in a bank's call center	5 minutes/transaction
Primary care encounter	15 minutes/patient

$$\text{Capacity} = \frac{1}{\text{Processing time}}$$

Process Capacity

Process capacity – The maximum flow rate a process can provide per unit of time.

- This determines the maximum supply of the process.
- The process capacity is the smallest capacity of all resources in the process.

Demand Rate, Constraints, Throughput

Demand Rate – the number of flow units that customers want per unit of time

Capacity-constrained – the case in which demand exceeds supply and the flow rate is equal to process capacity

Demand-constrained – the case in which process capacity exceeds demand and thus the flow rate is equal to the demand rate

Throughput – a synonym for flow rate; the number of flow units flowing through the process per unit of time

How to Compute Flow Rate, Utilization, and Cycle Time

Flow Rate – the number of flow units exiting/completing the process per unit of time

$$\text{Flow rate} = \text{Minimum} \{ \text{Demand}, \text{Process capacity} \}$$

Utilization – the ratio between the flow rate and the resource capacity

$$\text{Utilization} = \frac{\text{Flow rate}}{\text{Capacity}}$$

Cycle time – the time between completing two consecutive flow units

$$\text{Cycle time} = \frac{1}{\text{Flow rate}}$$

Cycle Time vs. Lead Time

- **Cycle time** – $1/\text{Flow rate}$. Cycle time is expressed in units of time per unit and is the amount of time between consecutive completed output.
- **Lead time** – the time between when an order is placed and when it is received. Process lead time is frequently used as an alternative term for **flow time**.

Be careful not to confuse the terms cycle time and lead time

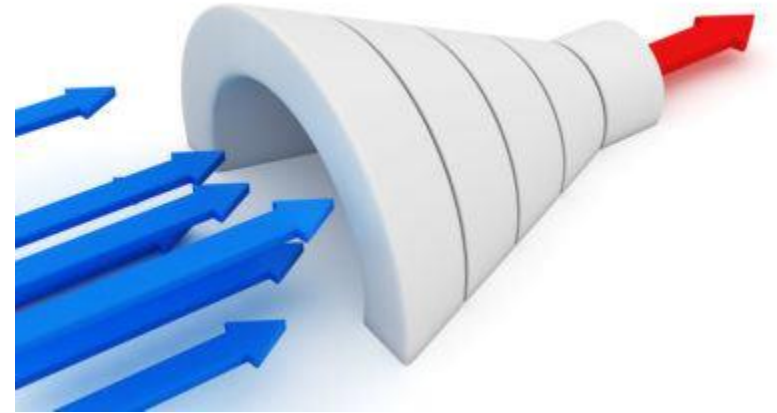
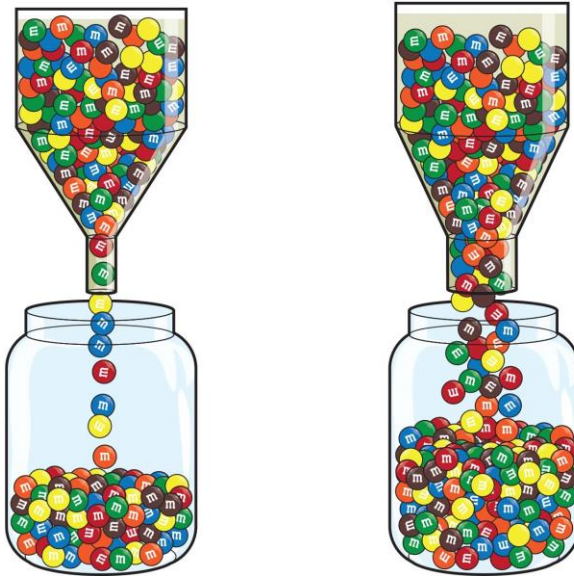
Remember Little's Law

Because cycle time is driven by flow rate and lead time is the same as flow time, you may notice that cycle time and lead time are related by Little's Law. Because $I = R \times T$, and $\text{Cycle time} = 1/R$ (thus $R = 1/\text{Cycle time}$), we get $I \times \text{Cycle time} = \text{Flow time}$.

Bottlenecks

Bottleneck – Resource with the lowest capacity in a process.

- Understanding the location of the bottleneck is critical for improving a process.



Bottleneck and Resource Utilization

In general, a resource might have utilization of less than 100 percent for one of two reasons:

1. A non-bottleneck resource has, by definition, some extra capacity relative to the bottleneck.
2. In the case of a demand-constrained process, even the bottleneck would not be working at 100 percent.

Process pacing and TFT

Worker paced: A process line in which each resource is free to work at its own pace.

- If the first resource finishes before the next one is ready to accept the flow unit, then the first resource puts the completed flow unit in the inventory between the two resources.

Machine paced: A process in which all steps are connected through a conveyor belt and all the steps must work at the same rate even if some of them have more capacity than others.

Time through the empty system (Theoretical Flow Time): The time it takes the first flow unit to flow through an empty process; that is, a process that has no inventory.

The Time to Produce a Certain Quantity: Two Cases

- System is Busy:

$$\text{Time to make } Q \text{ units} = \text{Cycle time} \times Q$$

- System is Empty:

$$\begin{array}{l} \text{Time to finish } X \text{ units} \\ \text{starting with an empty system} \end{array} = \begin{array}{l} \text{Time through} \\ \text{an empty process} \end{array} + [(X - 1) \times \text{Cycle time}]$$

Process Efficiency



Efficiency –high flow rate with few resources (i.e., low cost).

Profit Maximization and efficiency

Setting ethical considerations aside, we can think of profit maximization as the primary goal for most businesses.

$$\textit{Profit} = \textit{Flow rate} \times (\textit{Average price} - \textit{Average cost})$$

Obtaining high output at low costs is the key idea behind efficiency.

Efficiency is only one of multiple dimensions of operational performance. Businesses should not set efficiency as their only goal.

Measures of Process Efficiency

Costs of direct labor – The labor cost associated with serving one customer, which is the total wages paid per unit of time divided by the flow rate.

$$\text{Costs of direct labor} = \frac{\text{Wages per unit of time}}{\text{Flow rate}}$$

Labor content – The amount of work that goes into serving one customer (generally one flow unit) which is the sum of the processing times involving labor.

$$\text{Labor content} = \text{Sum of the processing times involving labor}$$

- A high number is less desirable than a low number.
- Focus on the ratio of input to output.

Average labor utilization – the average utilization across resources

$$\text{Average labor utilization} = \text{Average utilization across employees}$$

- Measure of efficiency.
- Average labor utilization should be as high as possible.

$$\text{Average labor utilization} = \frac{\text{Labor Content}}{\text{Cycle time} \times \text{Number of employees}}$$

Measures of Process Efficiency

Idle time – the amount of time per flow unit for which a resource is paid but is not actually working

Total idle time – the amount of idle time per flow unit added up across all resources



$$\text{Total idle time} = \text{Cycle Time} \times \text{Number of employees} - \text{Labor Content}$$

How to Choose a Staffing Level to Meet Demand

Takt time – the ratio between the time available and the quantity that must be produced to serve demand

- Goal to design a process flow that meets the demand rate



$$\text{Takt time} = \frac{\text{Available time}}{\text{Required quantity}}$$

$$\text{Takt time} = \frac{1}{\text{Demand rate}}$$

Takt time – Cycle time

- **Takt time** = $1/\text{Demand rate}$
 - Takt time does not depend on process capacity.
 - Takt time is driven by demand rate.
- **Cycle time** – $1/\text{Flow rate}$ (and the flow rate is the minimum of demand and process capacity)
 - Cycle time depends on process capacity.

In the spirit of matching supply with demand, the goal is to have a cycle time that is as close to the Takt time as possible.

How to Choose Staffing Level to Meet Demand

Target manpower - minimum number of resources required to meet demand.

$$\text{Target Manpower} = \frac{\text{Labor Content}}{\text{Takt Time}}$$

Staffing Process Improvement

In most businesses, the **demand varies**; it could be by the hour of the day, day of the week, or the time of year.

Leveling Demand – Setting an expected demand rate for a given period of time so that one can look for an appropriate staffing plan for that time period.

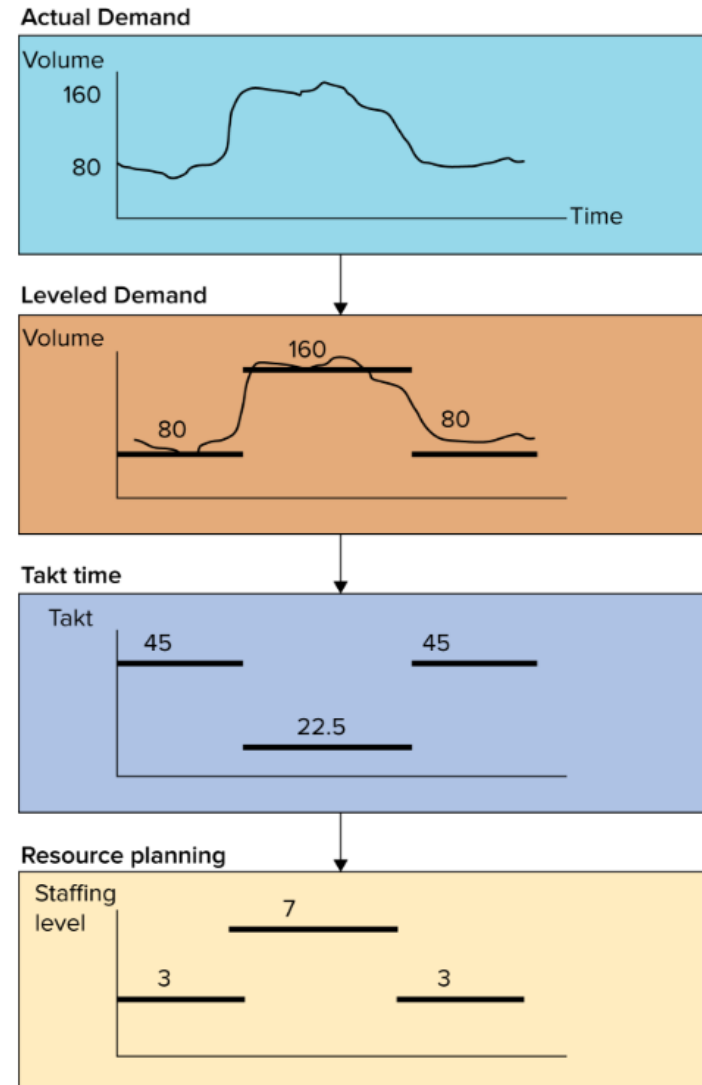


Figure 4.2 Demand leveling and its impact on staffing



Off-Loading the Bottleneck and Line Balancing

- **Line Balancing** - Reassign activities to other resources with more capacity.
 - Automating time-consuming activities
 - Outsourcing some of the activities
 - Consider adding more employees or consider overtime.
- Balance a process by allocating the activities that need to be carried out in the process across the process resources as evenly as possible.
 - Balancing for a fixed sequence of activities
 - Balancing for activities with no fixed sequence

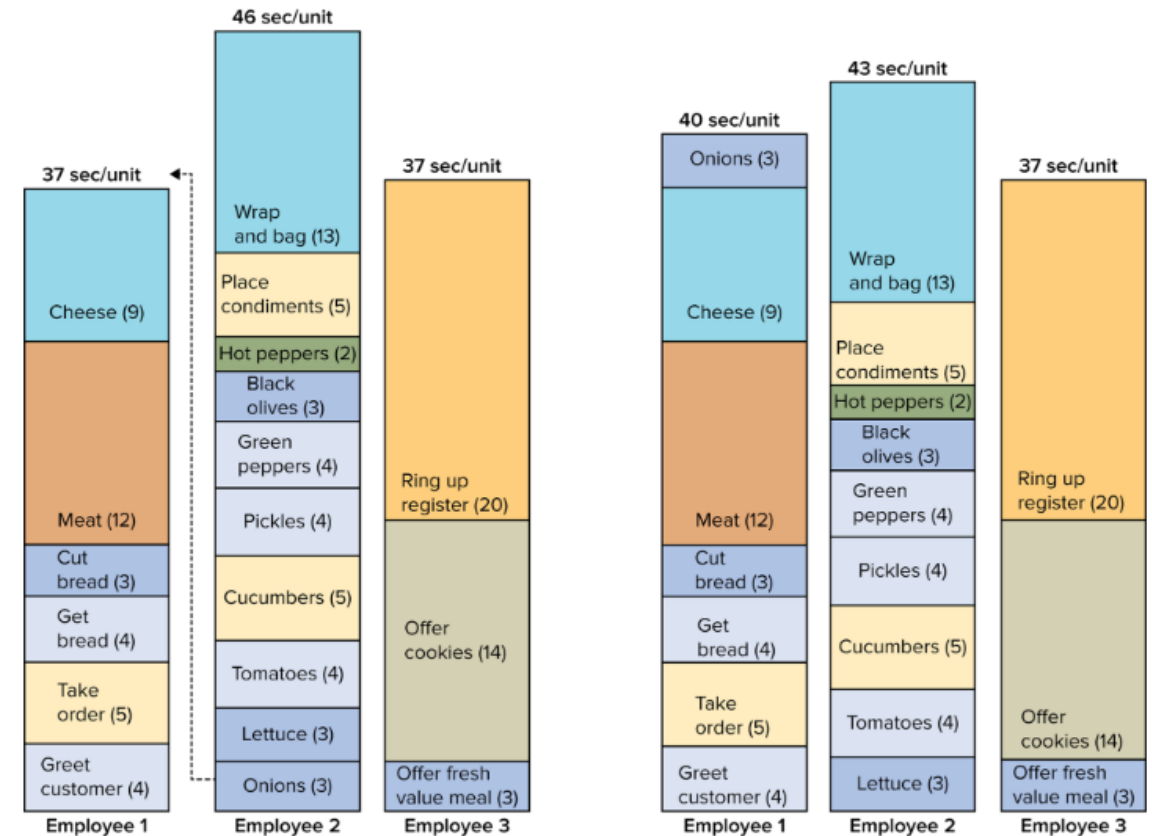


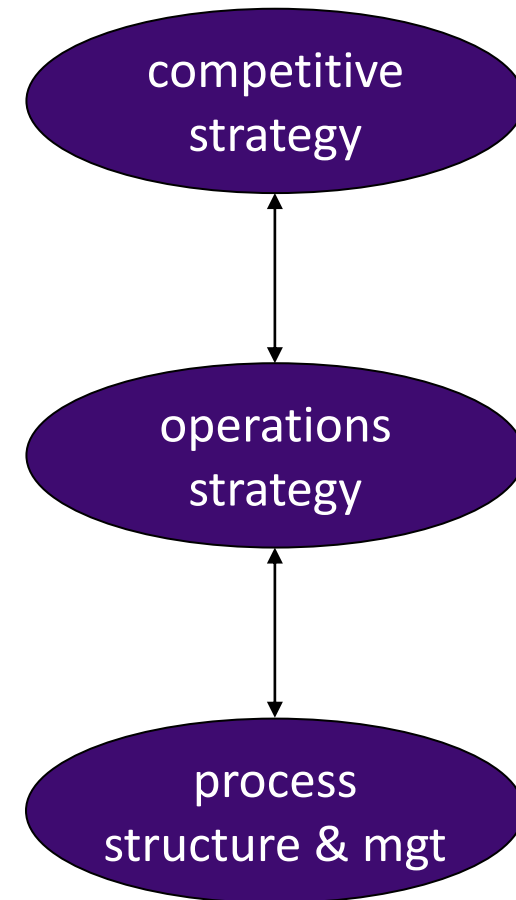
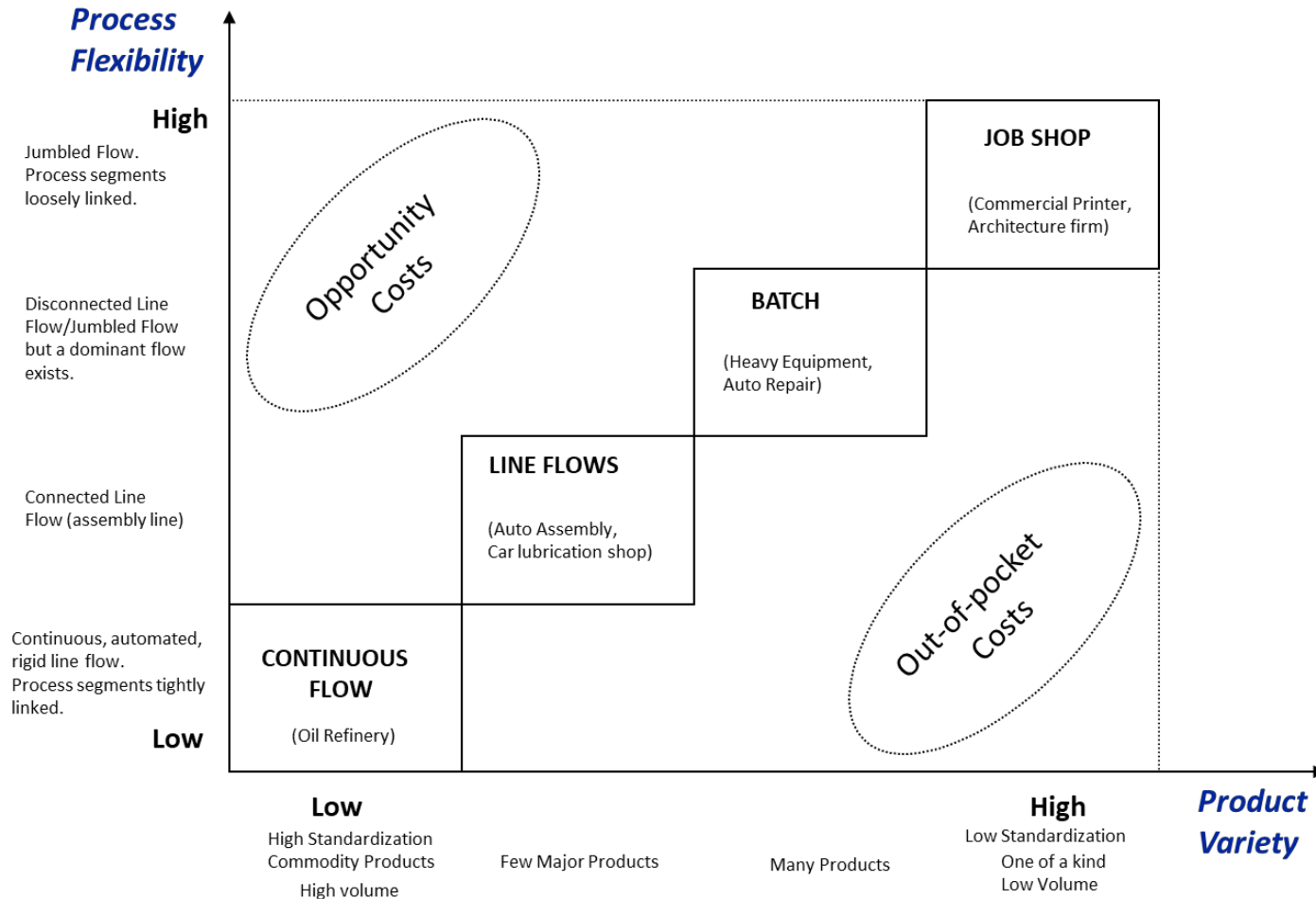
Figure 4.5 By moving an activity away from the bottleneck, we can increase capacity

Worker Cells as a hybrid approach

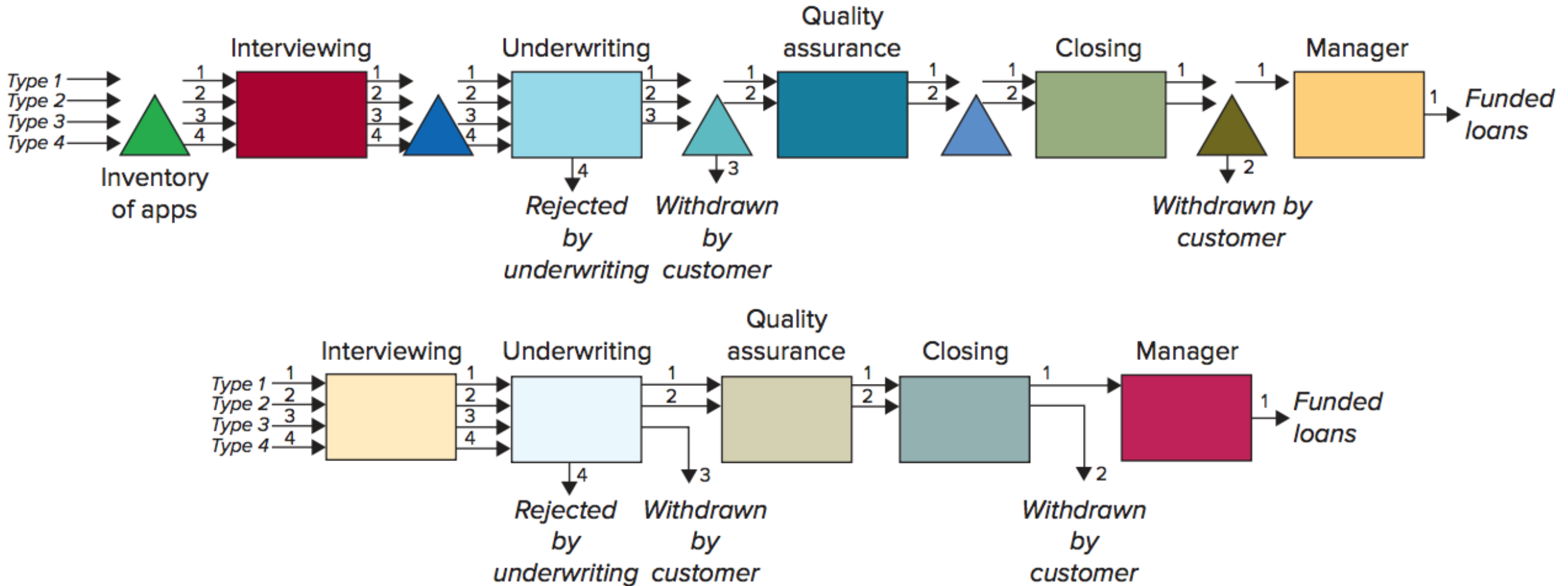
Work cells are a potential option: An organization of work where small teams perform a job from start to finish. (opposite of specialization)



The Product-Process Matrix: Choose a process aligned with your strategy



Process Flow Diagram with Multiple Flows



Demand Table: multiple flows with the same processing times

- **Demand table** – a table depicting the resources (rows) and demand flows (columns) through a process.
- Each cell is the demand rate for the (column's) flow type on that (row's) resource
- Total Demand Rate for a given resource is the row sum of the demand rates from all flow types

How do we find the **Bottleneck** with multiple flows?

- Before (Ch 3 and 4) we defined the bottleneck as the **resource** with the lowest capacity.
- Now, not every flow unit will go to every resource
- We must refine our definition of bottleneck... But how?
- Since we have the total demand rate for each resource across all flow types, we need to look at the total demand rate on a resource **relative** to that resource's capacity.

$$\text{Implied utilization} = \frac{\text{Resource's total demand}}{\text{Resource's capacity}}$$

Utilization vs. Implied Utilization

Utilization – the ratio between flow rate (**R**) and capacity.

- Utilization only carries information about excess capacity (when demand is less than capacity)
- $U \leq 100\%$

Implied Utilization – the ratio between what could flow through the resource (demand) and what the resource can provide (capacity).

- Captures the mismatch between supply (capacity) and demand
- Implied utilization can exceed 100%
- If $IU > 100\%$, then the resource does not have capacity to meet demand
- Multiple resources can have $IU > 100\%$

So how do we find the bottleneck?

Bottleneck of a process with *multiple flow types*

Bottleneck - the resource with the **highest implied utilization**

$$\text{Implied utilization} = \frac{\text{Resource's total demand}}{\text{Resource's capacity}}$$

Workload Table: multiple flows with different processing times

- Similar to the demand table with resources in the rows and flow types in the columns
- Each cell is the **workload** demanded by a flow-type (column) on a resource (row) per unit time.
 - Workload - multiply the demand rate by the processing time
- Total Workload for a given resource is the row sum of the workload from all flow types

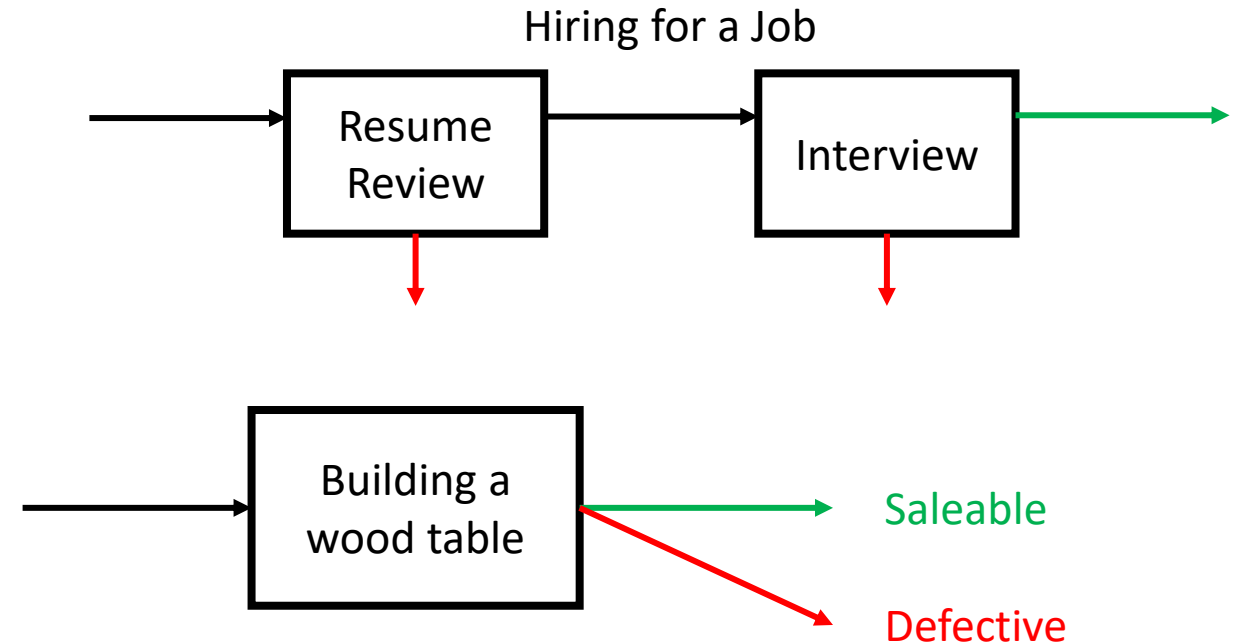
Bottleneck of a process with *multiple flow types* and *flow-dependent processing times*

Bottleneck - the resource with the **highest implied utilization**

$$\text{Implied utilization} = \frac{\text{Demand rate in minutes of work}}{\text{Capacity in minutes of work}}$$

Attrition Losses and Yields

- **Attrition loss** – all units start at the same resource but then drop out of the process (or are actively removed from the process) at different points.
- **Scrap** – defective flow units that are eliminated from the process.
- **Yield** – measures the percentage of good units that are output from the process with respect to the input

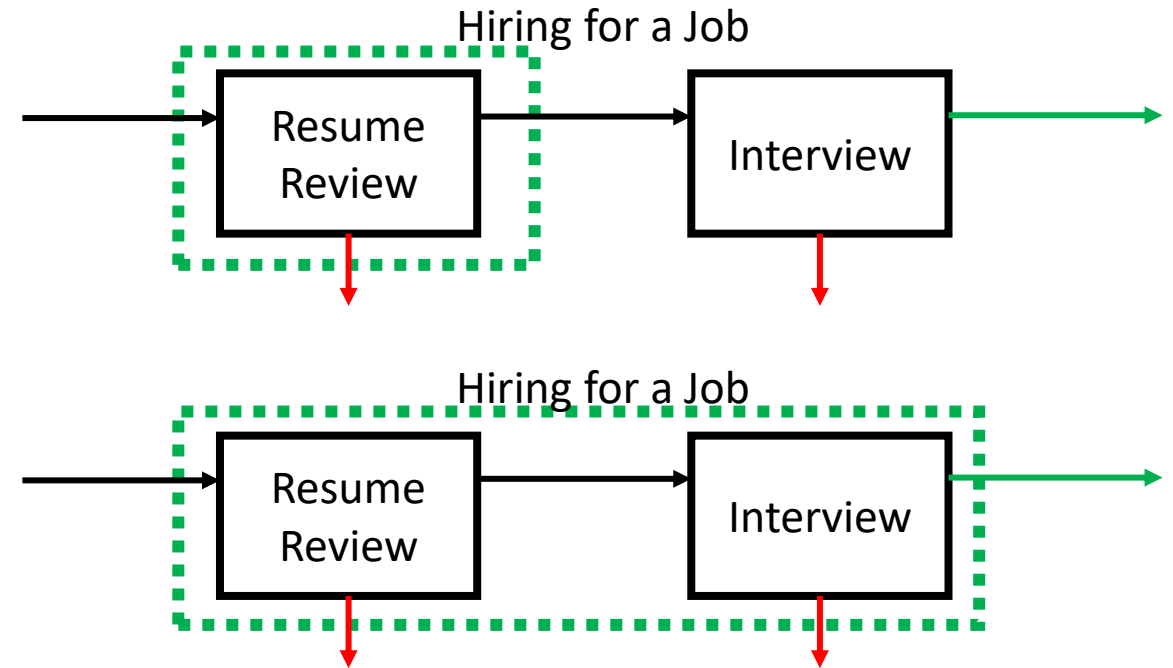


Attrition Losses and Yields

$$\begin{aligned}\text{Yield of resource} &= \frac{\text{Flow rate of good output at the resource}}{\text{Flow rate of input}} \\ &= 1 - \frac{\text{Flow rate of defects at the resource}}{\text{Flow rate of input}}\end{aligned}$$

$$\begin{aligned}\text{Process yield} &= \frac{\text{Flow rate of good output of the process}}{\text{Flow rate of input to the process}} \\ &= 1 - \frac{\text{Flow rate of defects in the process}}{\text{Flow rate of input to the process}}\end{aligned}$$

$$\text{Process yield} = y_1 \times y_2 \times y_3 \times \dots \times y_m$$



Rework

Rework – the repetition of activities or an extra set of activities that have to be completed by a defective flow unit in order to be restored to a good flow unit.

- Originated in the world of manufacturing.
- If rework is able to turn a defective unit into a good unit, the process yield returns to 100%.
- A resource needs to process more flow units.
 - The demand rate for a particular resource is higher relative to a situation not involving rework.

