

# Introduction to Logistics & Supply Chain Management: Key Concepts



# Agenda

- Push vs. Pull Systems
- Segmentation Strategies
  - Products
  - Supply Chains
- Handling Uncertainty

# Push vs. Pull Processes

# You can learn almost everything about logistics from a sandwich shop



Make to Order  
Make to Stock  
Engineer to Order

How many different sandwiches can be made?

Sandwich = Bread + Protein + Spread + Topping

18            6            10            20

21,600 Unique  
Sandwiches!



By Jimmy John's Franchise, LLC [http://upload.wikimedia.org/wikipedia/commons/e/e3/Jimmy\\_John\\_employees\\_having\\_fun\\_making\\_sandwiches.jpg](http://upload.wikimedia.org/wikipedia/commons/e/e3/Jimmy_John_employees_having_fun_making_sandwiches.jpg)  
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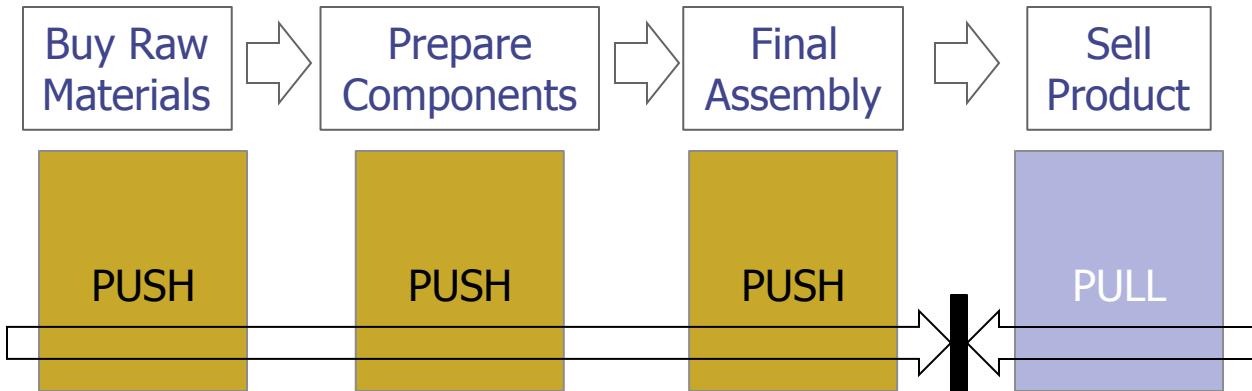
# Pull vs Push Processes

- Push –
  - Execution is performed in anticipation of an order
  - Demand is forecasted
  - Proactive process based on projected need/demand
- Pull –
  - Execution is performed in response to an order
  - Demand is actual and known with certainty
  - Reactive process based on actual need/demand
- Push / Pull Boundary
  - Point where push processes are separated from pull processes

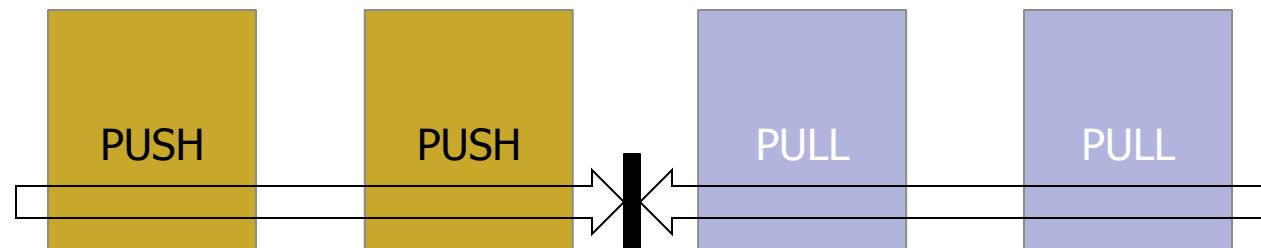
# Story of Three Sandwiches



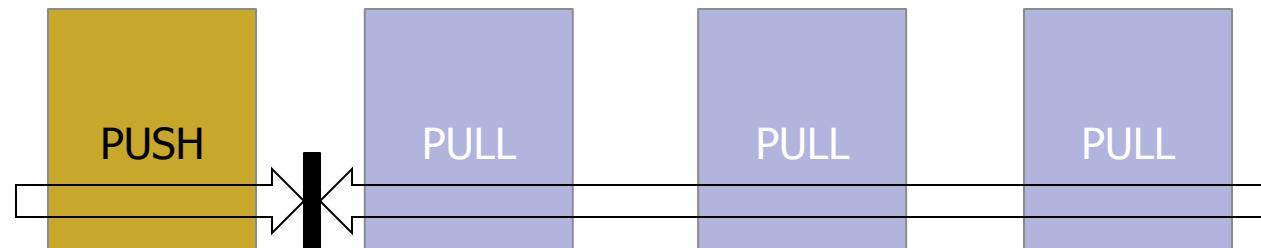
Ready Made Turkey Wrap



Signature Ham Sandwich



One-of-a-Kind Dagwood



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# Push vs Pull Processes

- What about pure systems?
  - Pure push – leads to higher inventory levels and potential spoilage / imbalance but faster cycle time
  - Pure pull – very rare
- Mixed systems are common – Where is the Push-Pull Point?
  - Push undifferentiated, raw product or components
  - Pull finished product
- Benefits of mixed systems
  - Allows for efficient mass customization (Postponement)
  - Allows for pooling of products – aggregating demand
- Key Principles
  - Maximize external variety with minimal internal variety
  - Keep in-process inventory as “Raw as Possible” (RAP)

# Segmentation

# Supply Chain Segmentation

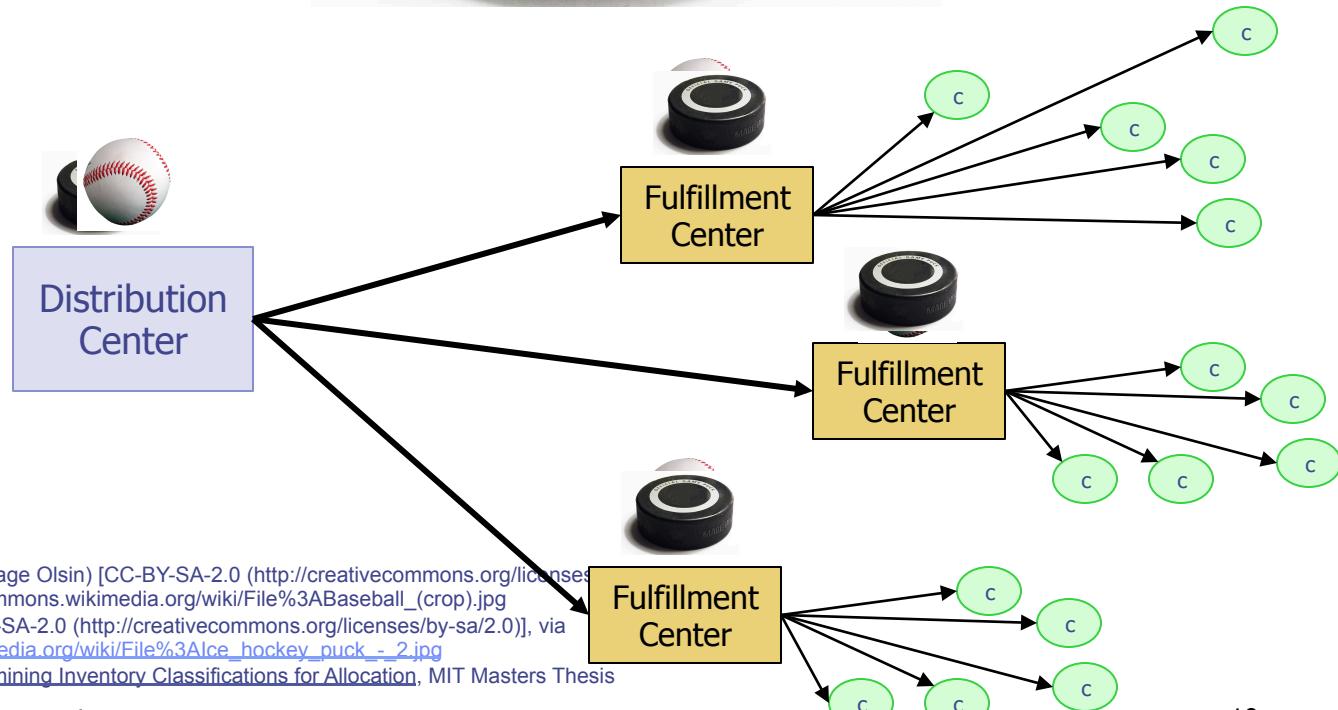
- In reality . . .
  - Firms operate multiple supply chains
  - There is no such thing as a one-size-fits-all supply chain
  - Firms segment in order to match the right method to the right product/customer/supplier combination
  - Firms can segment products, customers, suppliers, etc.
- Segmentation only makes sense if you do something different in how you buy, make, move, store or sell!
- Purchasing / Procurement
- Forecasting / Demand Planning
- Inventory Planning
- Inventory Control
- Warehousing / Materials Handling
- Order Management
- Transportation Management
- Customer Service

# How should I treat these products differently?



Summer

Winter



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Ball, Braden (2012) [Simulation as a Method for Determining Inventory Classifications for Allocation](#), MIT Masters Thesis

# Supply Chain Segmentation

- How many segments? (Rules of thumb)
  - **Homogenous**- within the segment should be similar
  - **Heterogeneous**- across segments should be very different
  - **Critical Mass** - should be big enough to make it worthwhile
  - **Pragmatic** - dimensions should be useful and communicable
- How can I segment my customers or suppliers?

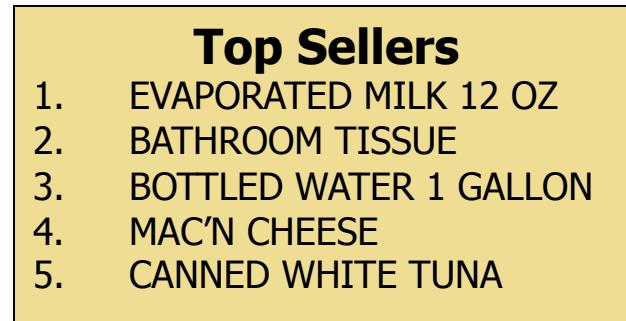
Lead time	Service Level
Purchase History	Order Size/Volume
Geography	Demographic
Sales Trends	Channel Segmentation
Strategic Importance	
- How can I segment my products?
  - Physical characteristics (value, size, density, etc.)
  - Demand characteristics (sales volume, volatility, sales duration, etc.)
  - Supply characteristics (availability, location, reliability, etc.)

Adapted from Prashant Yadav (2005) Course Notes, Zaragoza Logistics Center.

# Distribution of SKUs

# Product Segmentation

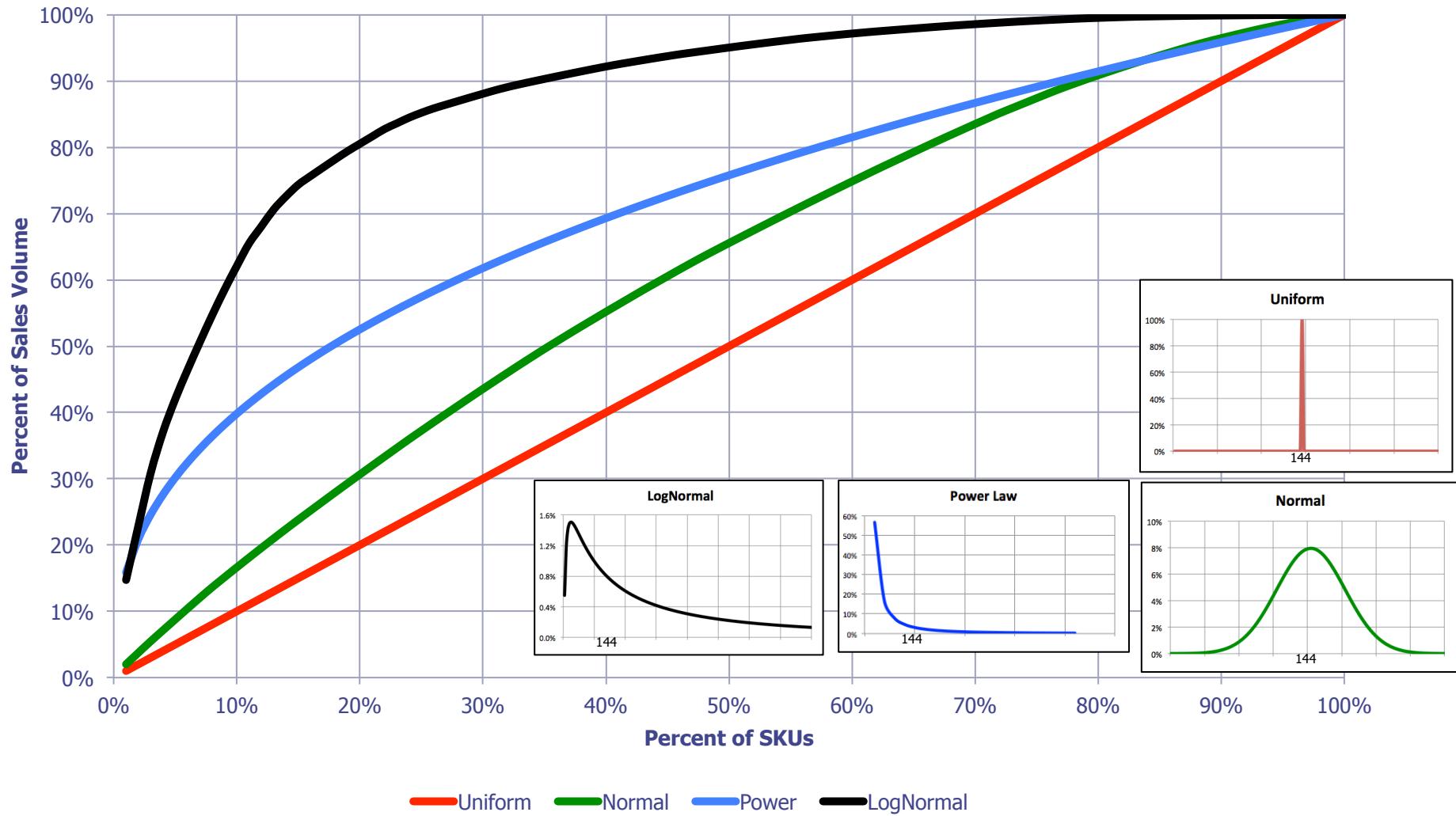
- Local Grocery Store
  - ~20,000 SKUs
  - Categories: Dry, Frozen, & Perishables
- Analysis of Dry Goods (~8,000 SKUs)
  - 1.156 M SKUs sold in 1 year
  - Number of units sold per SKU
    - ◆ Mean 144
    - ◆ Median 72
    - ◆ Mode 0
    - ◆ Std Dev 355
- Biggest Sellers?
- Biggest Sales Day?

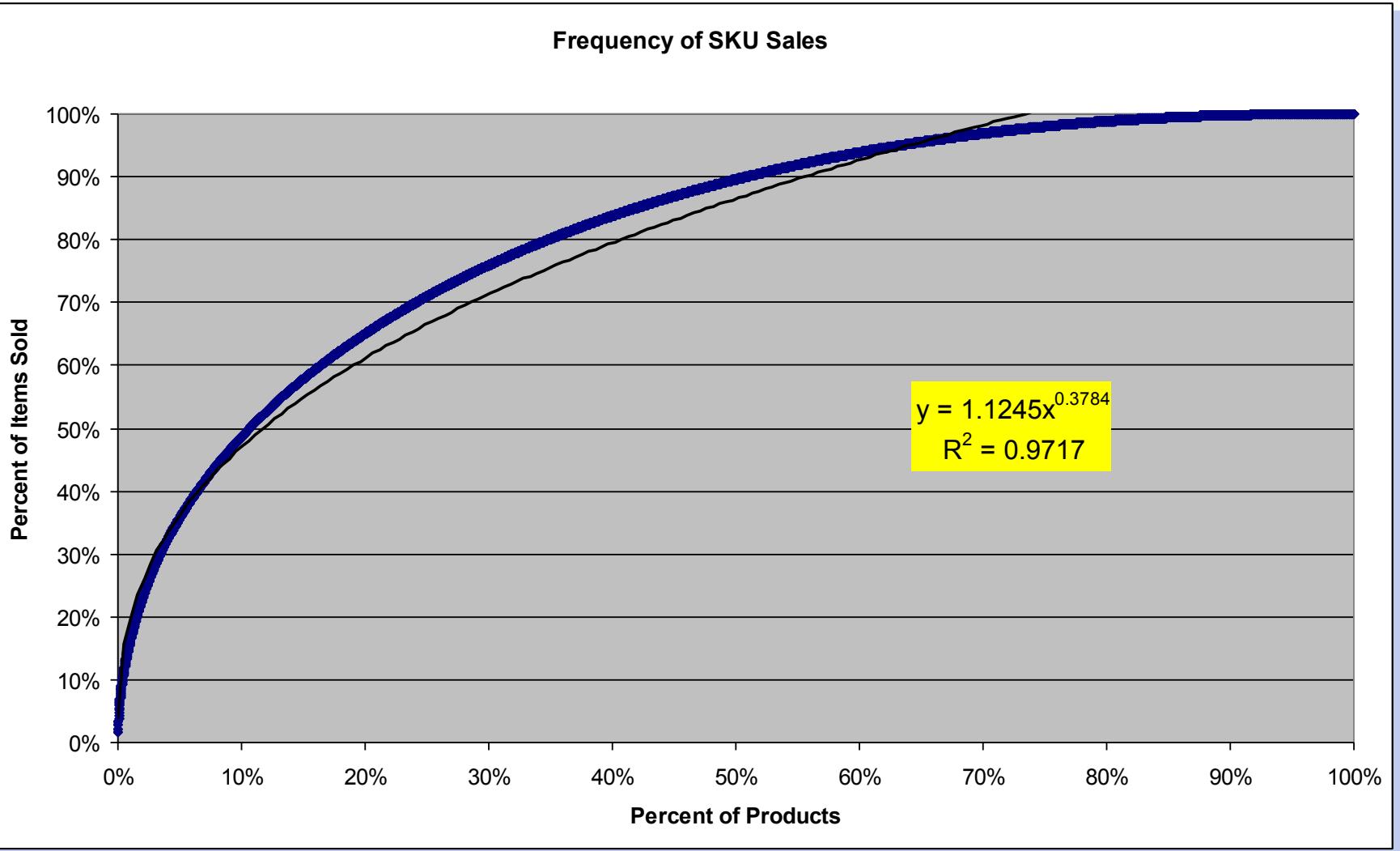


How are products distributed in terms of sales volume?  
Uniform? Normal? Other?

Kerslake, Christopher (2005) [A Method for Analyzing the Delivery Frequency From a Distribution Center to a Retail Grocery Store](#), MIT Masters Thesis  
"Faced products on a supermarket shelf" by Amnesiac86 - Own work. Licensed under Creative Commons Attribution-Share Alike 3.0 via Wikimedia Commons - [http://commons.wikimedia.org/wiki/File:Faced\\_products\\_on\\_a\\_supermarket\\_shelf.JPG#mediaviewer/File:Faced\\_products\\_on\\_a\\_supermarket\\_shelf.JPG](http://commons.wikimedia.org/wiki/File:Faced_products_on_a_supermarket_shelf.JPG#mediaviewer/File:Faced_products_on_a_supermarket_shelf.JPG).

# Potential Product Distributions

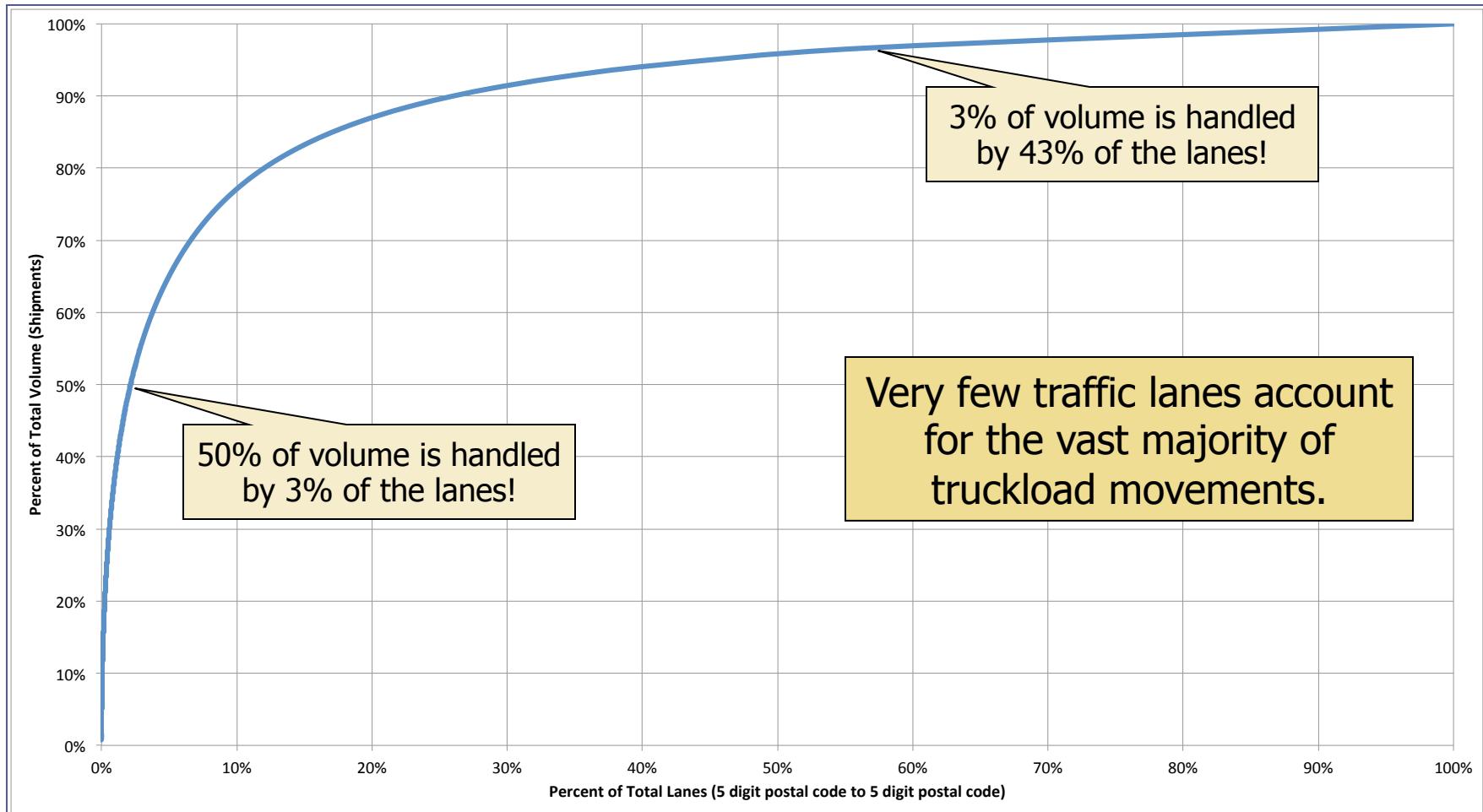




This is an example of the Power Law,  $y=ax^k$   
Why is this important?  
Is this distribution unique?

# Example: Distribution of Traffic on Lanes

Full Truckload movements between Postal Codes in US  
5 million shipments on ~400k lanes



# Power Law ( $y=ax^k$ )

- Exceptionally common in physical and social systems
  - Severity of hurricanes and earthquakes
  - Income within a population (Pareto's Law)
  - Visits to websites (Nielsen's Law) & blogs
  - Frequency of words in any language (Zipf's Law)
  - Frequency of digits within tables (Benford's Law)
  - Frequency of authors citations in literature (Lotka's Law)
  - Animals' metabolic rates with respect to mass (Kleiber's Law)
  - Profitability of customers & products
  - Distribution of volume on traffic lanes
  - Questions from students in a class

The *important few* versus the *trivial many*

## Fundamental Insight

Distribution of many phenomena across a population follow a Power Law relationship

# ABC Analysis

# Segmentation: ABC Analysis

- Class A Items - *the important few*
  - Very few high impact items are included
  - Require the most managerial attention and review
  - Expect many exceptions to be made
- Class B Items – *the middleshare*
  - Many moderate impact items (sometimes most)
  - Automated control w/ management by exception
  - Rules can be used for A (but usually too many exceptions)
- Class C Items - *the trivial many*
  - Many if not most of the items that make up minor impact
  - Control systems should be as simple as possible
  - Reduce wasted management time and attention
  - Group into common regions, suppliers, end users

**Remember – these are arbitrary classifications**

# Segmentation: ABC Analysis

Part ID	Price	Annual Demand	Annual \$ Value
5497J	\$ 2.25	260	\$ 585.00
3K62	\$ 2.85	43	\$ 122.55
88450	\$ 1.50	21	\$ 31.50
P001	\$ 0.77	388	\$ 298.76
2M993	\$ 4.45	612	\$ 2,723.40
3HHT8	\$ 6.10	220	\$ 1,342.00
56M4	\$ 3.10	110	\$ 341.00
89KE	\$ 1.32	786	\$ 1,037.52
45O3	\$ 12.80	14	\$ 179.20
55K2	\$ 24.99	334	\$ 8,346.66
978SD3	\$ 7.75	24	\$ 186.00
78HJQ2	\$ 0.68	77	\$ 52.36
23LK	\$ 0.25	56	\$ 14.00
990RT	\$ 3.89	89	\$ 346.21
58JH4	\$ 7.70	675	\$ 5,197.50
2340P	\$ 6.22	66	\$ 410.52
3784	\$ 0.85	148	\$ 125.80
38JQ2	\$ 0.77	690	\$ 531.30
56TT7	\$ 1.23	52	\$ 63.96
7UJS2	\$ 4.05	12	\$ 48.60
		4,677	<b>\$ 21,983.84</b>

1. Identify the SKUs that management should spend time on
2. Prioritize SKUs by their value to firm
3. Create logical groupings
4. Adjust as needed

Example:

- Sample of 20 SKUs
- Total of 4,677 units
- Total ~\$22k

# Segmentation: ABC Analysis

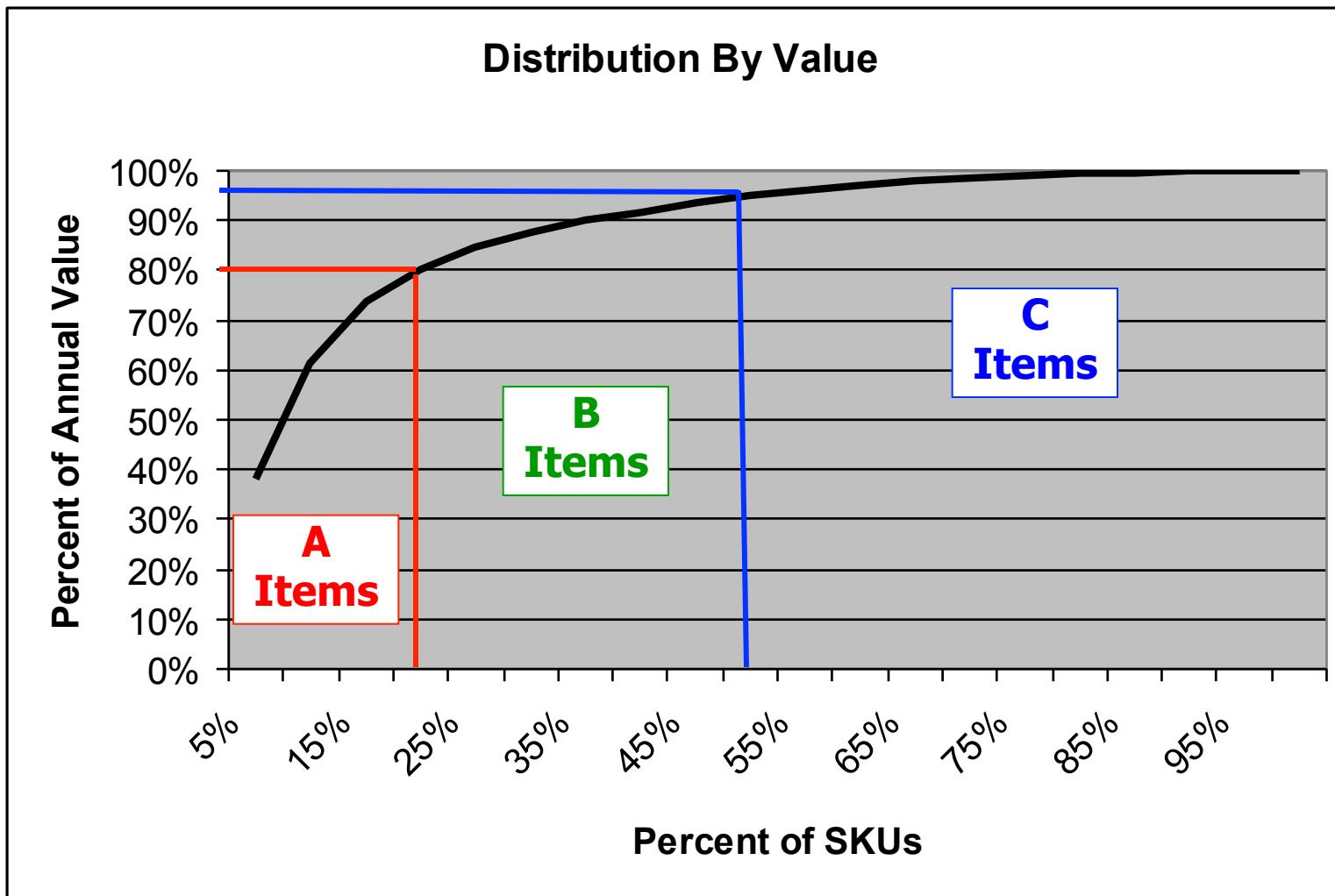
	$c_i$	$D_i$	$c_i D_i$	$\sum c_i D_i$	
Part ID	Price	Annual Demand	Annual \$ Value	Cum \$ Value	Pct Ann \$ Value
55K2	\$ 24.99	334	\$ 8,347	\$ 8,347	38%
58JH4	\$ 7.70	675	\$ 5,198	\$ 13,544	62%
2M993	\$ 4.45	612	\$ 2,723	\$ 16,268	74%
3HHT8	\$ 6.10	220	\$ 1,342	\$ 17,610	80%
89KE	\$ 1.32	786	\$ 1,038	\$ 18,647	85%
5497J	\$ 2.25	260	\$ 585	\$ 19,232	87%
38JQ2	\$ 0.77	690	\$ 531	\$ 19,763	90%
2340P	\$ 6.22	66	\$ 411	\$ 20,174	92%
990RT	\$ 3.89	89	\$ 346	\$ 20,520	93%
56M4	\$ 3.10	110	\$ 341	\$ 20,861	95%
P001	\$ 0.77	388	\$ 299	\$ 21,160	96%
978SD3	\$ 7.75	24	\$ 186	\$ 21,346	97%
45O3	\$ 12.80	14	\$ 179	\$ 21,525	98%
3784	\$ 0.85	148	\$ 126	\$ 21,651	98%
3K62	\$ 2.85	43	\$ 123	\$ 21,773	99%
56TT7	\$ 1.23	52	\$ 64	\$ 21,837	99%
78HJQ2	\$ 0.68	77	\$ 52	\$ 21,890	100%
7UJS2	\$ 4.05	12	\$ 49	\$ 21,938	100%
88450	\$ 1.50	21	\$ 32	\$ 21,970	100%
23LK	\$ 0.25	56	\$ 14	\$ 21,984	100%
		4,677	\$ 21,984		

A Items:  
80% of Value  
20% of SKUs

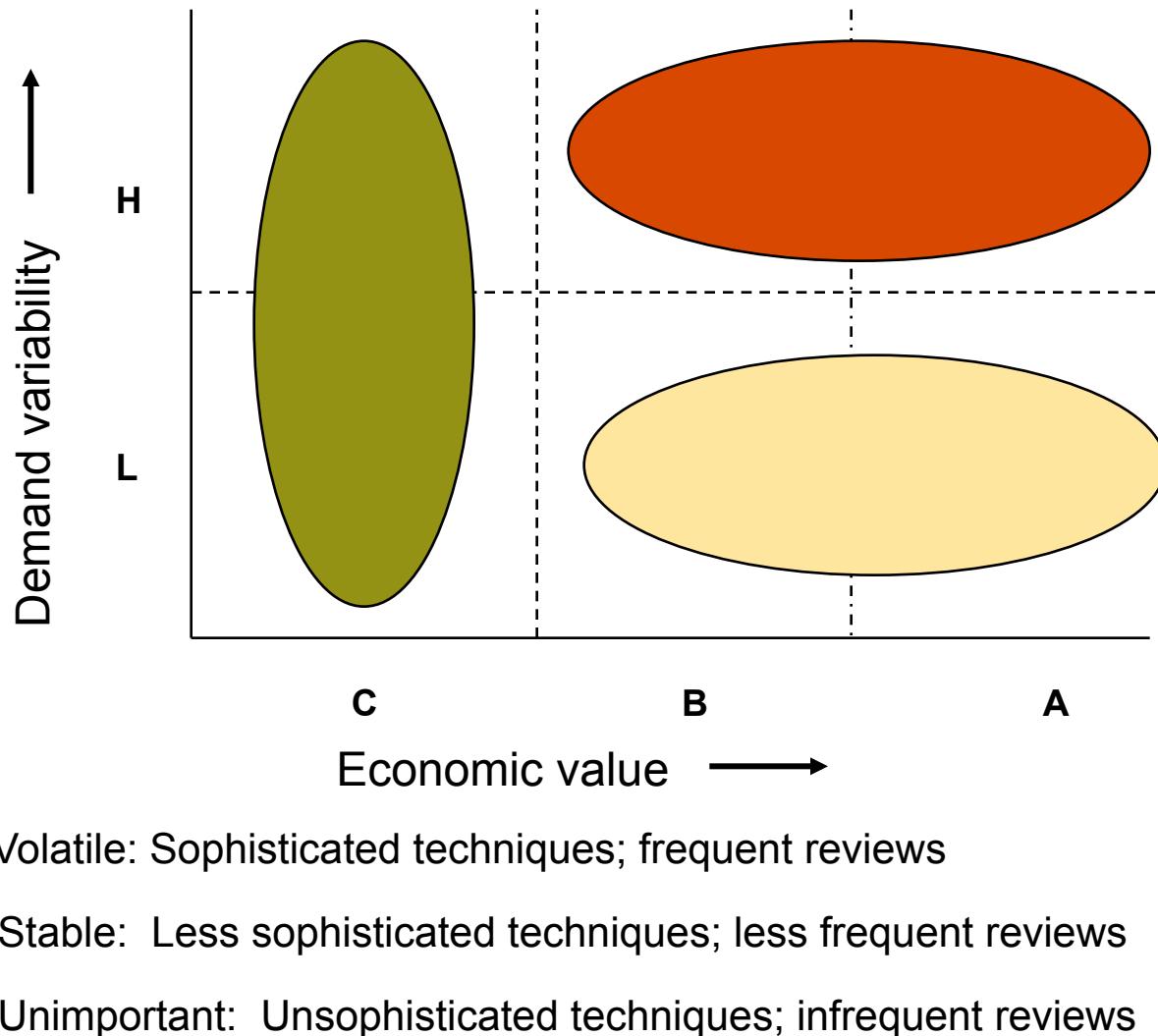
B Items:  
15% of Value  
30% of SKUs

C Items:  
5% of Value  
50% of SKUs

# Segmentation: ABC Analysis



# Segmentation: Other Methods



Adapted from Prashant Yadav (2005) Course Notes, Zaragoza Logistics Center.

# Segmenting Supply Chains

# Segmentation: Innovative vs. Functional



	Functional	Innovative
Demand		
Life Cycle		
Margin		
Variety		
Error at Production		
Avg Stockout Rates		
Forced Mark down		
Lead time for MTO		
Supply Chain Objective		

Source: Fisher, M. (1997) "What Is the Right Supply Chain for Your Product?", Harvard Business Review. Adapted from Sheffi (2010) ESD.260 Course Notes  
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# Supply Chain Portfolio

Decision variables for SC Design :  
(One option is chosen from each column)

	Fast / High Cost	Intermediate Design	Slow/Low Cost
Manufacturing Location			
International Shipping			
Final Assembly Location			
Order Fulfillment Location			
Inventory Stocking Model			

Source: Olavsun, Lee, & DeNyse (2010) "A Portfolio Approach to Supply Chain Design," Supply Chain Management Review. Adapted from Sheffi (2010) ESD.260 Course Notes

# Supply Chain Portfolio

Original Inkjet SC:



	Fast / High Cost	Intermediate Design	Slow/Low Cost
Manufacturing Location	On shore (e.g., US/Europe)		
International Shipping		Rail/Truck	
Final Assembly Location	On Shore		
Order Fulfillment Location	On Shore (Factory/ DC)		
Inventory Stocking Model	Build to Stock		

Source: Olavsun, Lee, & DeNyse (2010) "A Portfolio Approach to Supply Chain Design," Supply Chain Management Review. Adapted from Sheffi (2010) ESD.260 Course Notes "Hp500-1" by Oguenthaler - Own work. Licensed under Creative Commons Attribution-Share Alike 3.0 via Wikimedia Commons - <http://commons.wikimedia.org/wiki/File:Hp500-1.png#mediaviewer/File:Hp500-1.png>

# Supply Chain Portfolio

Postponement Inkjet SC:



	Fast / High Cost	Intermediate Design	Slow/Low Cost
Manufacturing Location			Off shore (e.g., China, Vietnam)
International Shipping			Ocean
Final Assembly Location	On Shore		
Order Fulfillment Location	On Shore (Factory/ DC)		
Inventory Stocking Model		Configure to Order	

Source: Olavsun, Lee, & DeNyse (2010) "A Portfolio Approach to Supply Chain Design," Supply Chain Management Review. Adapted from Sheffi (2010) ESD.260 Course Notes "Hp-deskjet-895xi". Licensed under Creative Commons Attribution-Share Alike 3.0 via Wikimedia Commons - <http://commons.wikimedia.org/wiki/File:Hp-deskjet-895xi.jpg#mediaviewer/File:Hp-deskjet-895xi.jpg>. "MFHP1600" by LupisSM - Own work. Licensed under Creative Commons Attribution-Share Alike 3.0-2.5-2.0-1.0 via Wikimedia Commons - <http://commons.wikimedia.org/wiki/File:MFHP1600.JPG#mediaviewer/File:MFHP1600.JPG>

# Supply Chain Portfolio

Cost Competition Inkjet:



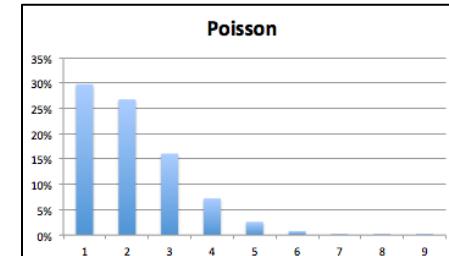
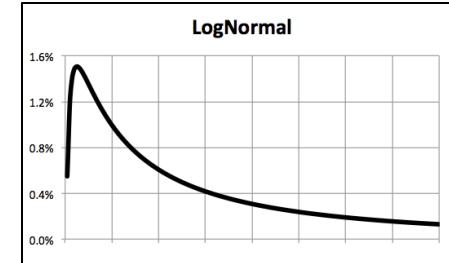
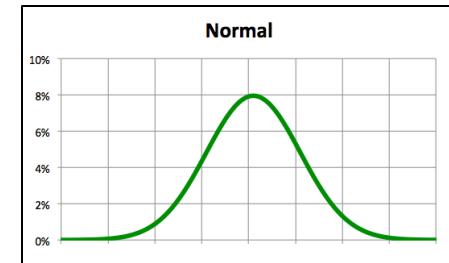
	Fast / High Cost	Intermediate Design	Slow/Low Cost
Manufacturing Location			Off shore (e.g., China, Vietnam)
International Shipping			Ocean
Final Assembly Location			Off Shore
Order Fulfillment Location	On Shore (Factory/ DC)		
Inventory Stocking Model	Build to Stock		

Source: Olavsun, Lee, & DeNyse (2010) "A Portfolio Approach to Supply Chain Design," Supply Chain Management Review. Adapted from Sheffi (2010) ESD.260 Course Notes "MFHP1600" by LupisSM - Own work. Licensed under Creative Commons Attribution-Share Alike 3.0-2.5-2.0-1.0 - <http://commons.wikimedia.org/wiki/File:MFHP1600.JPG#mediaviewer/File:MFHP1600.JPG>

# Handling Uncertainty

# Variability & Uncertainty

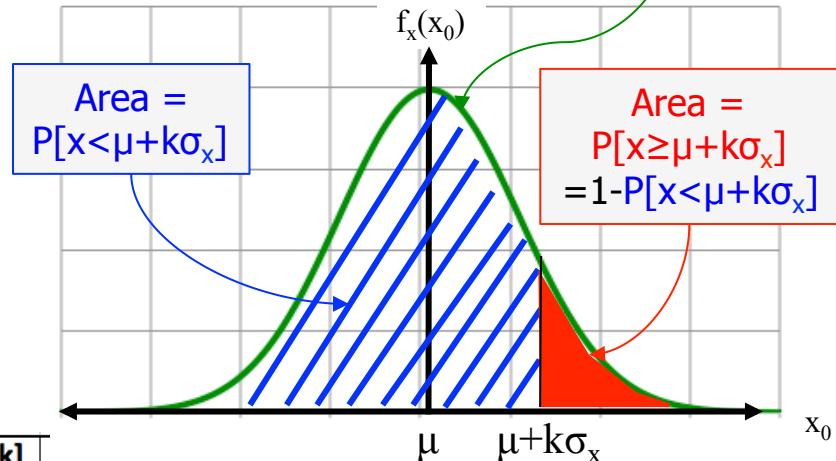
- Occurs in all aspects of supply chains
- Managing to the “mean” or “average” is rarely sufficient
- Handled by assuming a probability distribution
  - Normal Distribution  $\sim N(\mu, \sigma)$ 
    - ◆ Continuous ( $-\infty < x < +\infty$ ) and Symmetric
    - ◆ Most commonly used – for good or worse
  - Log-normal Distribution  $\sim \Lambda(\mu^*, \sigma^*)$ 
    - ◆ Continuous ( $0 < x < +\infty$ ) and Skewed left
    - ◆ Less common – but good for supply chains
  - Poisson Distribution  $\sim P(\lambda)$ 
    - ◆ Discrete (integers  $\geq 0$ )
    - ◆ Commonly used for low valued distributions



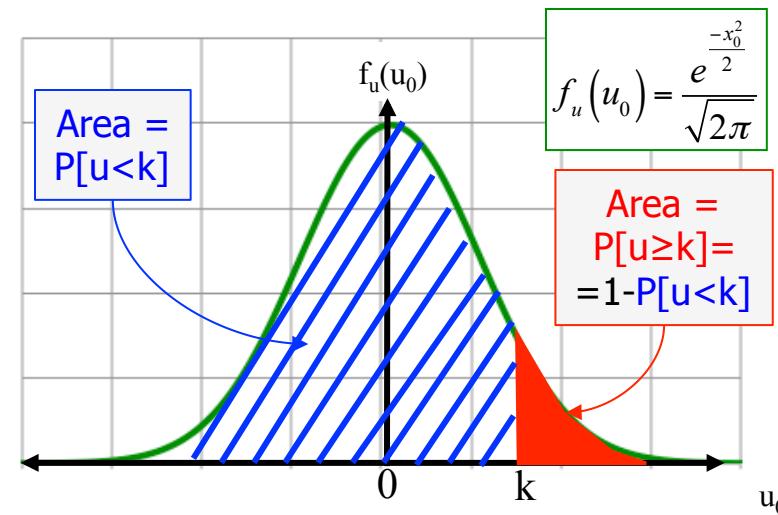
# Normal Distribution

- Normal  $\sim N(\mu, \sigma)$ 
  - Spreadsheets
    - $\text{NORMINV}(\text{probability}, \mu, \sigma) = \mu + k\sigma_x$
    - $\text{NORMDIST}(x, \mu, \sigma, 1) = P[x < \mu + k\sigma_x]$
- Unit Normal  $\sim N(0, 1)$ 
  - Transformation:  $k = (x - \mu) / \sigma_x$
  - Spreadsheets
    - $\text{NORMSINV}(\text{probability}) = k$
    - $\text{NORMSDIST}(k) = P[u < k]$
  - Standard Unit Normal Tables
    - Look up  $k$  or  $P[u < k]$
- Confidence Intervals
  - $\mu \pm \sigma$  68.3%
  - $\mu \pm 2\sigma$  95.5%
  - $\mu \pm 3\sigma$  99.7%

$$f_x(x_0) = \frac{e^{\frac{-(x_0-\mu)^2}{2\sigma_x^2}}}{\sigma_x \sqrt{2\pi}}$$



$k$	$P[u < k]$
0.50	0.6915
0.51	0.6950
0.52	0.6985
0.53	0.7019
0.54	0.7054
0.55	0.7088
0.56	0.7123

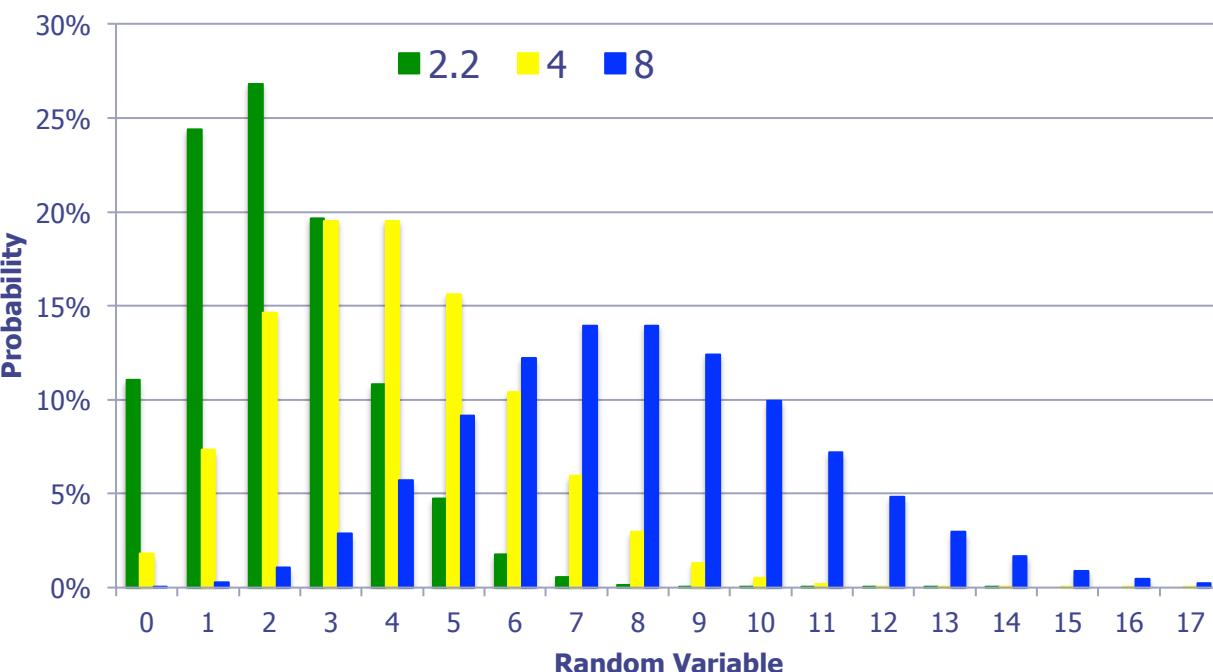


# Poisson Distribution

- Poisson  $\sim P(\lambda)$ 
  - Probability of  $x$  events occurring w/in a time period
  - Mean = Variance =  $\lambda$
- In Spreadsheets:
  - $p(x_0) = \text{POISSON}(x_0, \lambda, 0)$
  - $F(x_0) = \text{POISSON}(x_0, \lambda, 1)$

$$p[x_0] = \text{Prob}[x = x_0] = \frac{e^{-\lambda} \lambda^{x_0}}{x_0!} \quad \text{for } x_0 = 0, 1, 2, \dots$$

$$F[x_0] = \text{Prob}[x \leq x_0] = \sum_{x=0}^{x_0} \frac{e^{-\lambda} \lambda^x}{x!}$$



## Poisson Tables (partial)

- Columns:  $\lambda$
- Rows:  $F(x_0)$

$F(x)$	0.75	1.00
0	0.47237	0.36788
1	0.82664	0.73576
2	0.95949	0.91970
3	0.99271	0.98101
4	0.99894	0.99634
5	0.99987	0.99941
6	0.99999	0.99992
7	1.00000	0.99999
8	1.00000	1.00000

# Key Points from Lesson

# Key Points from Lesson

- Push vs. Pull Systems
  - Push – proactive based on forecast demand
  - Pull – reactive based on actual demand
- Benefits of Mixed Systems
  - Maximize external variety with minimal internal variety
  - Keep in-process inventory as “Raw as Possible” (RAP)
  - Postponement & Aggregated Demand
- Segmentation Strategies
  - Segment for a purpose (functional vs. innovative)
  - Product segmentation (ABC) – good starting point
- Handling Uncertainty
  - Normal Distribution
  - Poisson Distribution

# Questions, Comments, Suggestions? Use the Discussion!



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