# Introduction to Logistics & Supply Chain Management:
## Key Concepts

MIT Center for
Transportation & Logistics

# 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

## How many different sandwiches can be made?

Sandwich = Bread + Protein + Spread + Topping

18 6 10 20

21,600 Unique Sandwiches!

Make to Order
Make to Stock
Engineer to Order

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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

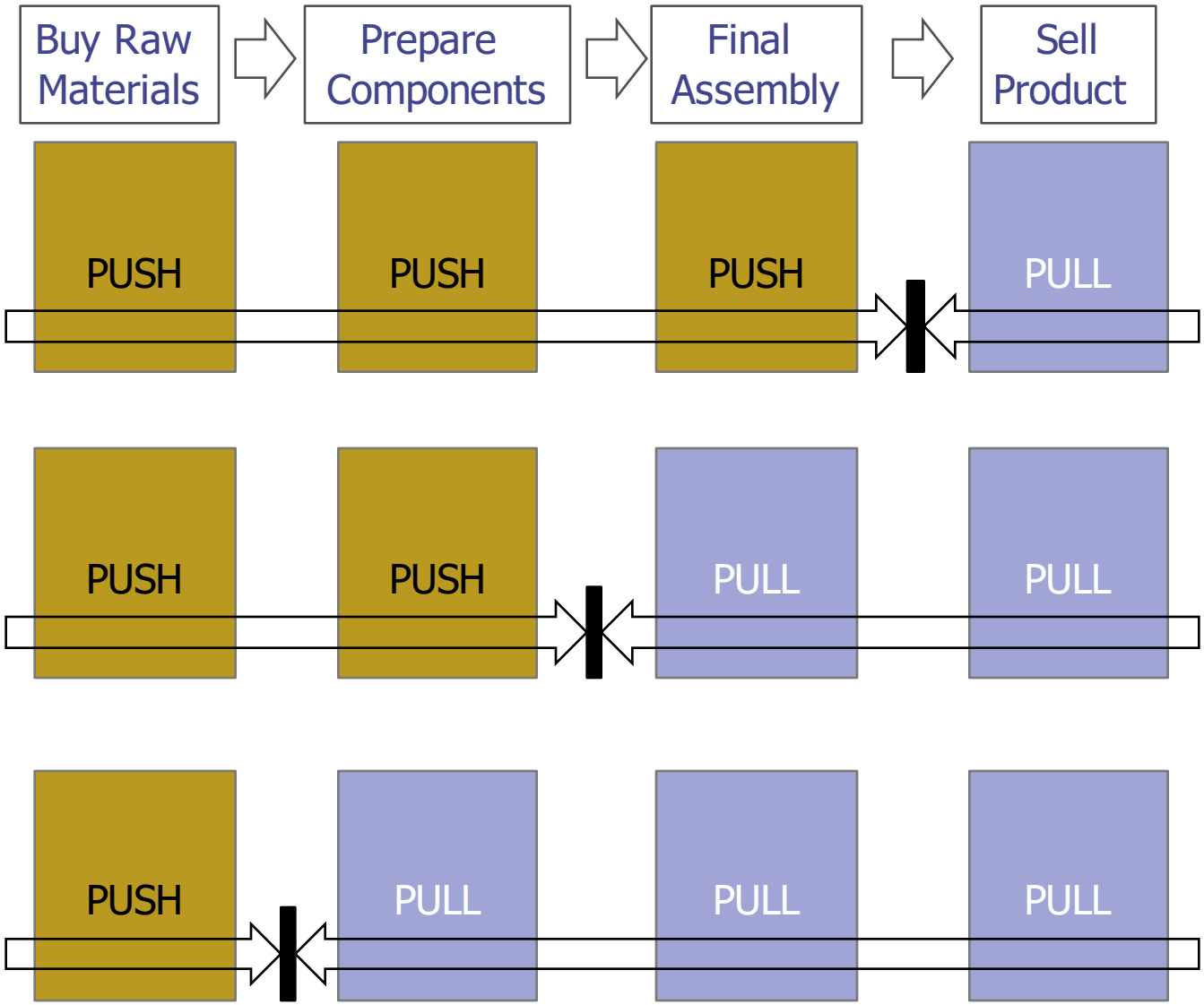
- Push / Pull Boundary
  - Point where push processes are separated from pull processes

# 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

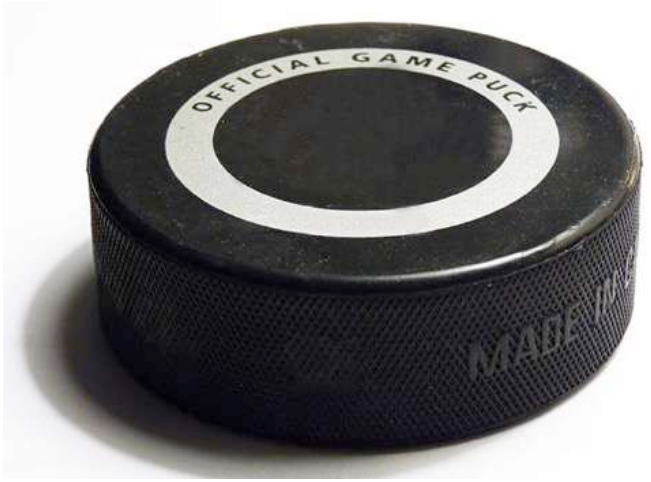
# Supply Chain Segmentation

- 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!

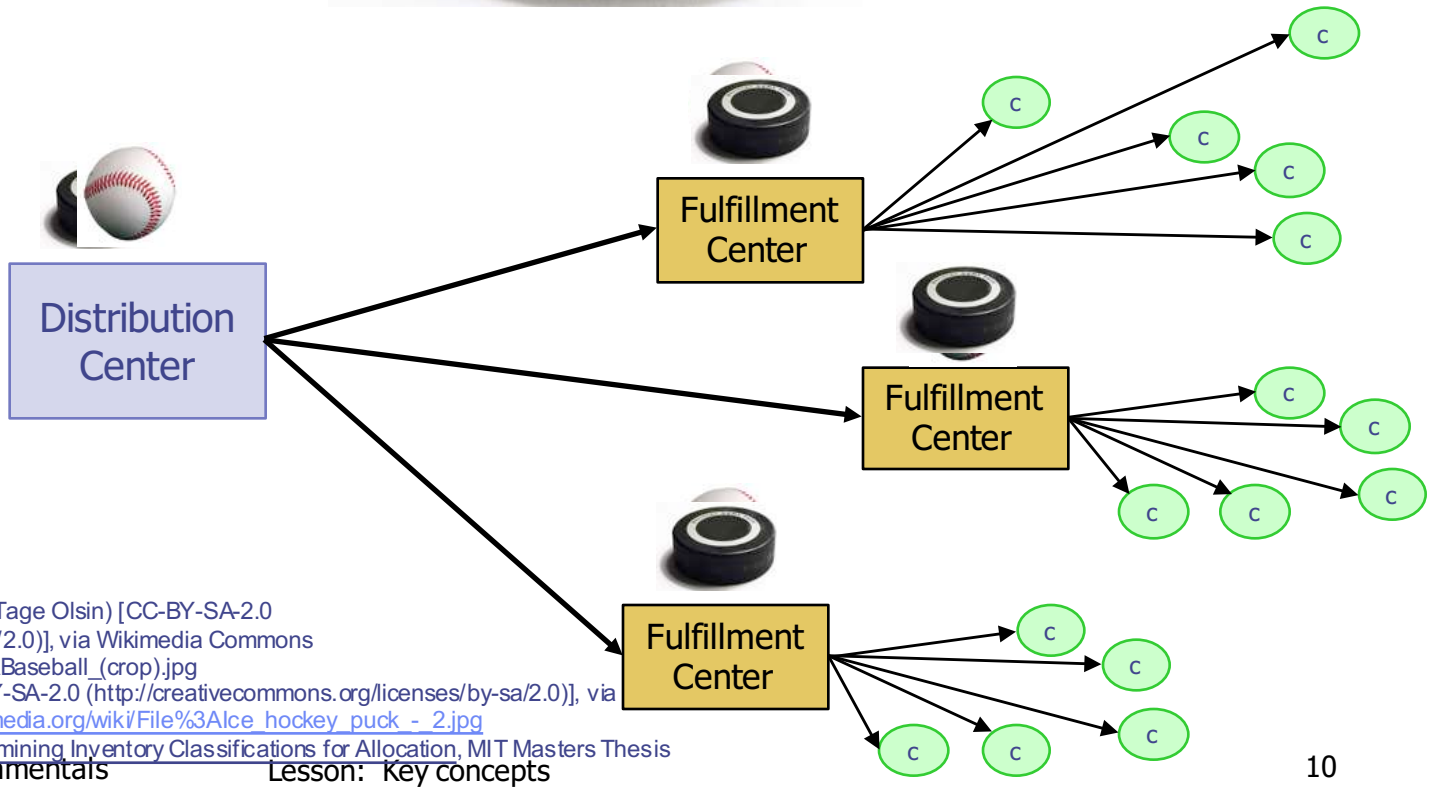
- Purchasing / Procurement
- Forecasting / Demand Planning
- Inventory Planning
- Inventory Control
- Warehousing / Materials Handling
- Order Management
- Transportation Management
- Customer Service

# 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?

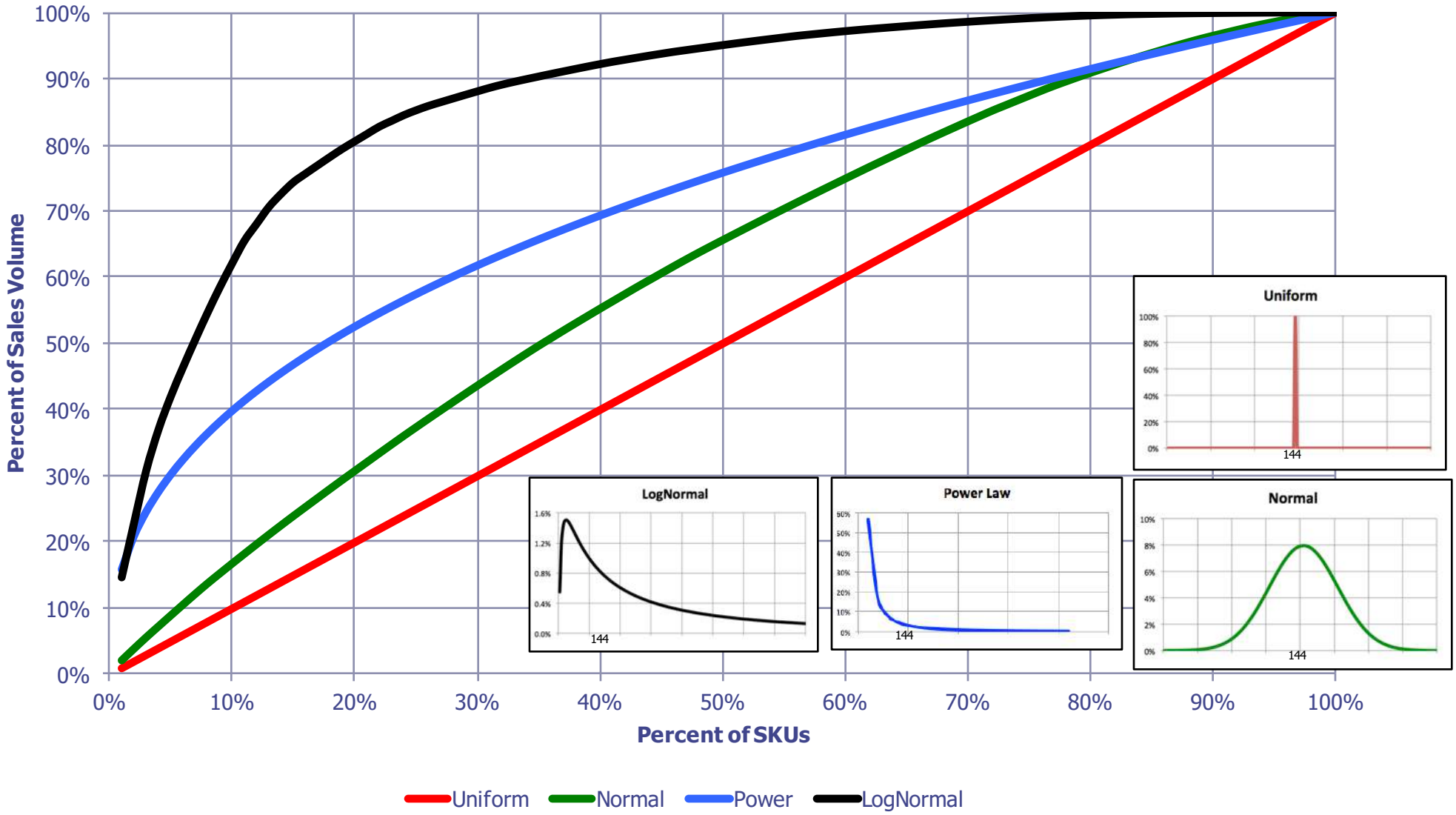
**Top Sellers**

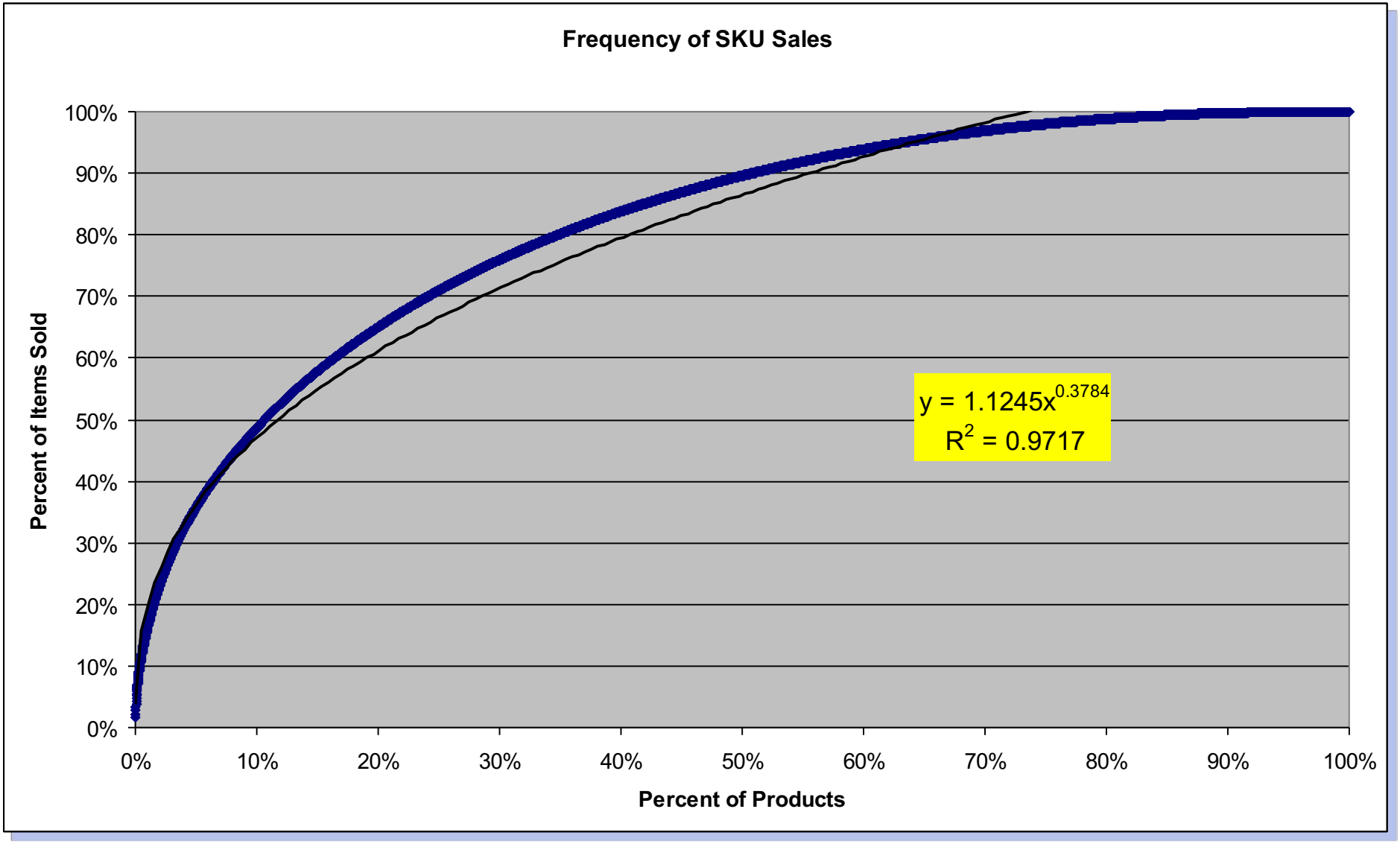
1. EVAPORATED MILK 12 OZ
2. BATHROOM TISSUE
3. BOTTLED WATER 1 GALLON
4. MAC'N CHEESE
5. CANNED WHITE TUNA

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

# Potential Product Distributions





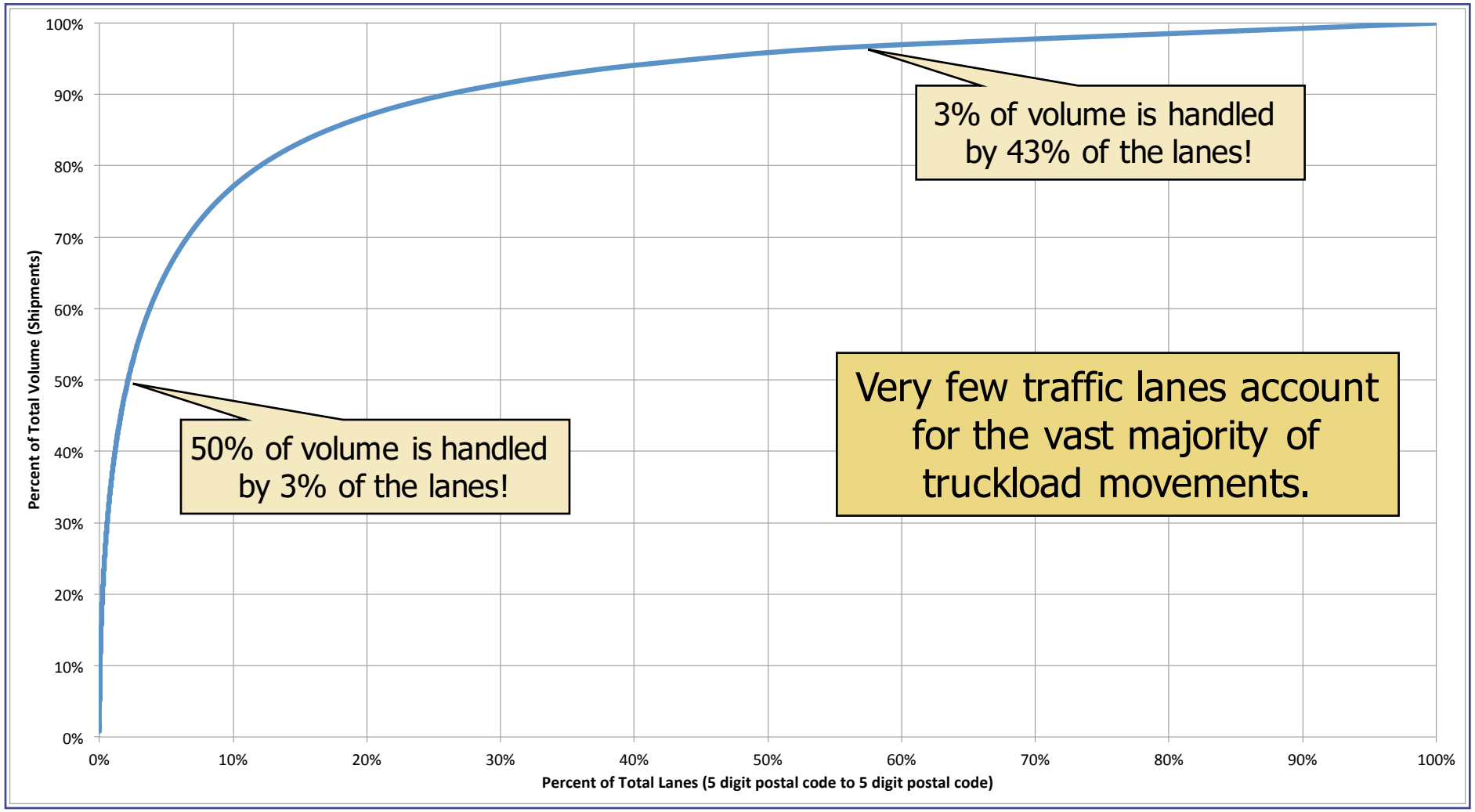

This is an example of the Power Law, $y=ax^k$

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

| | $c_i$ | $D_i$ | $c_i D_i$ |
|---|---|---|---|
| **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 | **$ 21,983.84** |

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

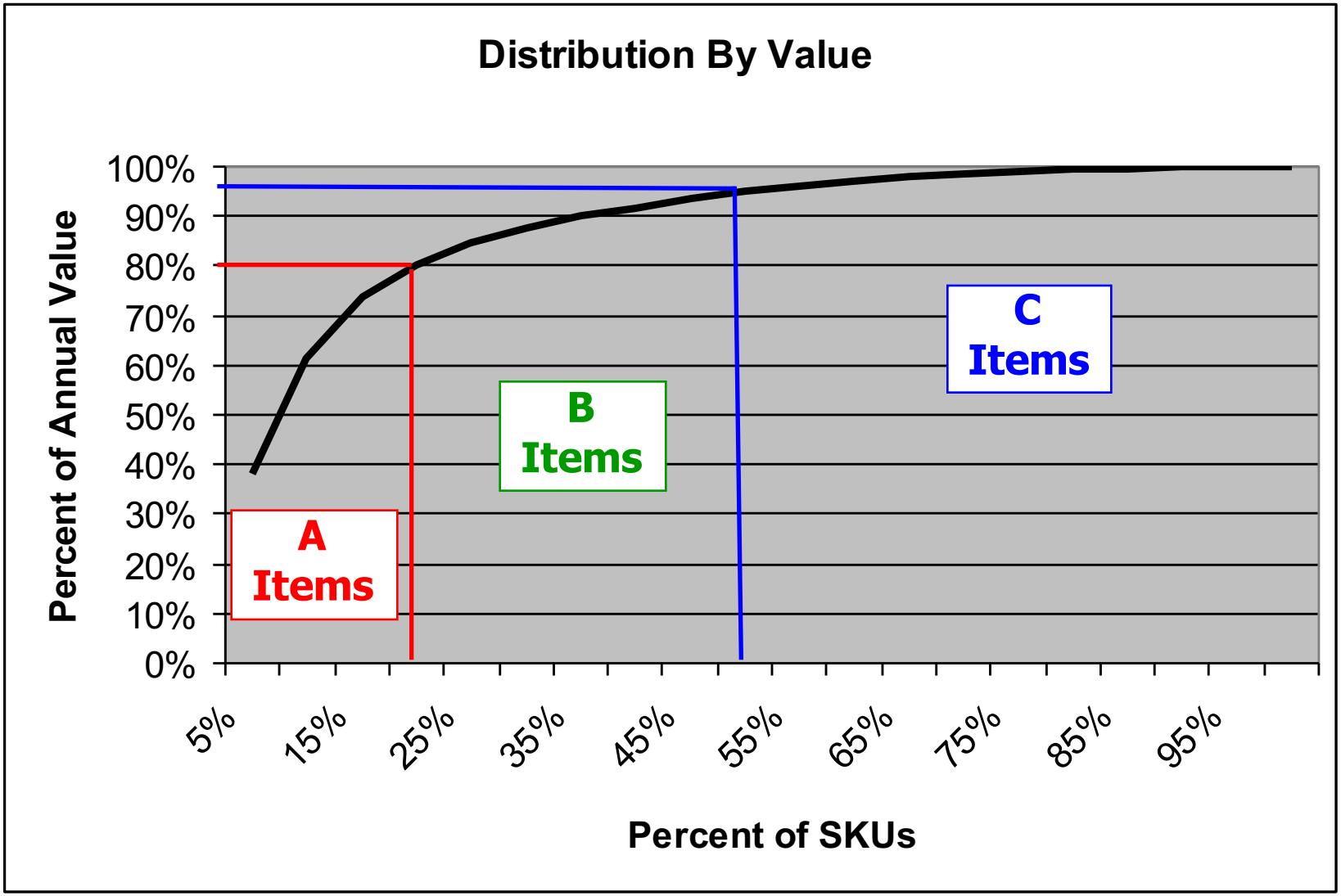
| | | $c_i$ | $D_i$ | $c_iD_i$ | $\Sigma c_iD_i$ | |
|---|---|---|---|---|---|---|
| **Part ID** | **Price** | | **Annual Demand** | **Annual $ Value** | **Cum $ Value** | **Pct Ann $ Value** |
| 55K2 | $ 24.99 | | 334 | $ 8,347 | $ 8,347 | 38% |
| 58JH4 | $ 7.70 | | 675 | $ 5,198 | $ 13,544 | 62% |
| 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**

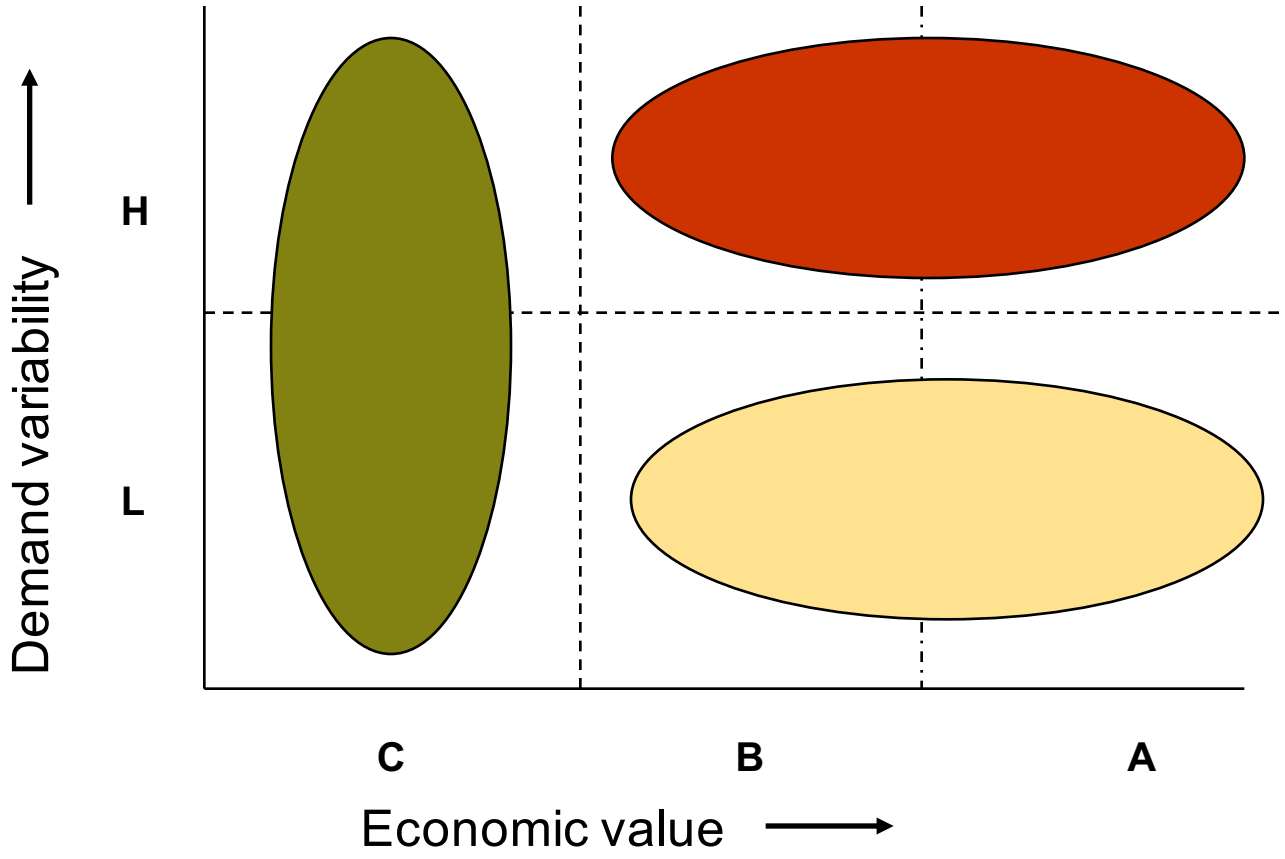
**B Items:**
**15% of Value**
**30% of SKUs**

**C Items:**
**5% of Value**
**50% of SKUs**

# Segmentation: ABC Analysis



# Segmentation: Other Methods




Volatile: Sophisticated techniques; frequent reviews

Stable: Less sophisticated techniques; less frequent reviews

Unimportant: Unsophisticated techniques; infrequent reviews

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

# Segmenting Supply Chains

# Segmentation: Innovative vs. Functional


| | Functional | Innovative |
|---|---|---|
| Demand | Predictable | Unpredictable |
| Life Cycle | Long > 2 yrs | Short <1 yr |
| Margin | 5% to 20% | 20% to 60% |
| Variety | Low (10-20) | High |
| Error at Production | ~10% | ~40-100% |
| Avg Stockout Rates | 1% to 2% | 10% to 40% |
| Forced Mark down | 0% | 10% - 25% |
| Lead time for MTO | 6 mon to 1 yr | 1 day to 2 wks |
| Supply Chain Objective | Efficiency | Match Supply & Demand |

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

# 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 | On shore (e.g., US/Europe) | Near shore (e.g., Mexico/ Romania) | Off shore (e.g., China, Vietnam) |
| International Shipping | Air Freight | Rail/Truck | Ocean |
| Final Assembly Location | On Shore | Near Shore | Off Shore |
| Order Fulfillment Location | On Shore (Factory/DC) | Near Shore (Factory/DC) | Off Shore (Factory/DC) |
| Inventory Stocking Model | Build to Stock | Configure to Order | Build 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

# 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
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# 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
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# 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
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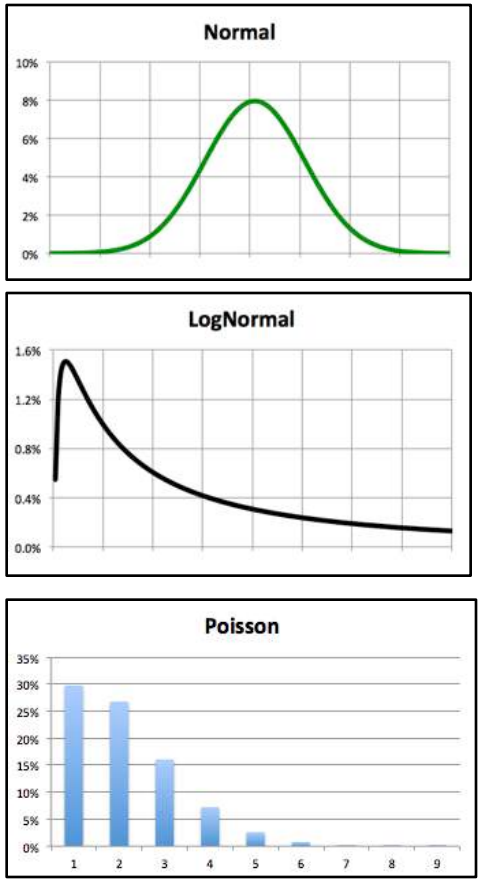
# Handling Uncertainty

# Variability & Uncertainty

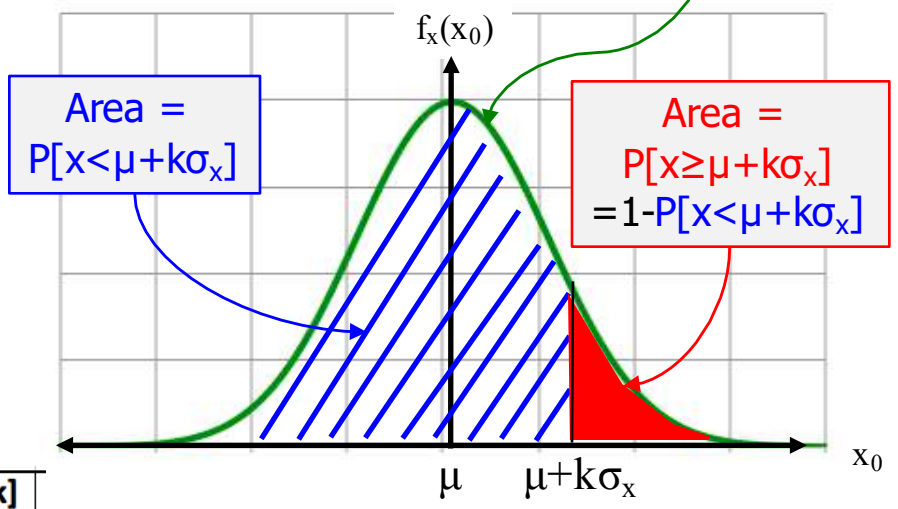
- Occurs in all aspects of supply chains
- Managing to the "mean" or "average" is rarely sufficient
- Handled by assuming a probability distribution
  - Normal Distribution ~N(μ, σ)
    - Continuous (-∞<x<+∞) and Symmetric
    - Most commonly used – for good or worse
  - Log-normal Distribution ~Λ(μ*, σ*)
    - Continuous (0<x<+∞) and Skewed right
    - Less common – but good for supply chains
  - Poisson Distribution ~P(λ)
    - Discrete (integers ≥0)
    - Commonly used for low valued distributions



# Normal Distribution

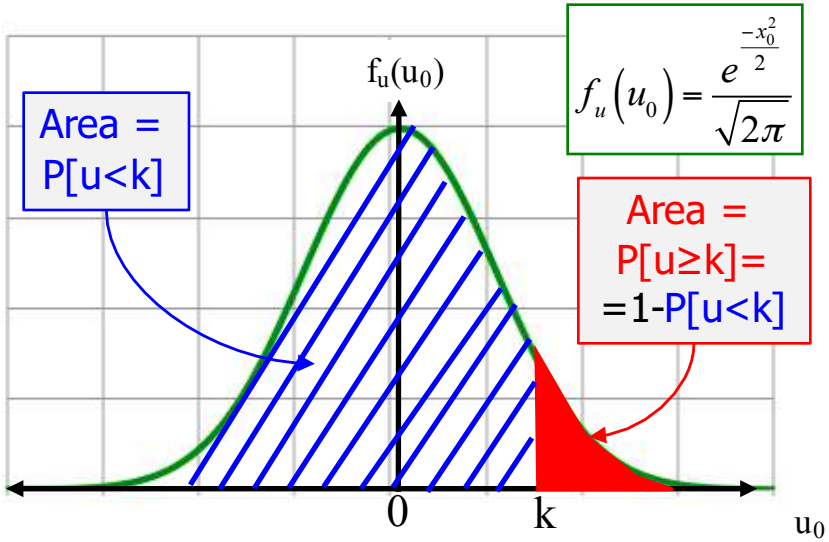
- Normal ~N(μ, σ)
  - Spreadsheets
    - NORMINV(probability,μ,σ) =$\mu+k\sigma_x$
    - NORMDIST(x,μ,σ,1) =P[x<$\mu+k\sigma_x$]
- Unit Normal ~N(0,1)
  - Transformation: k = $(x-\mu)/\sigma_x$
  - Spreadsheets
    - NORMSINV(probability) =k
    - NORMSDIST(k) =P[u<k]
  - Standard Unit Normal Tables
    - Look up k or P[u<k]
- Confidence Intervals
  - μ ± σ 68.3%
  - μ ± 2σ 95.5%
  - μ ± 3σ 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 |

$$f_u(u_0) = \frac{e^{\frac{-x_0^2}{2}}}{\sqrt{2\pi}}$$

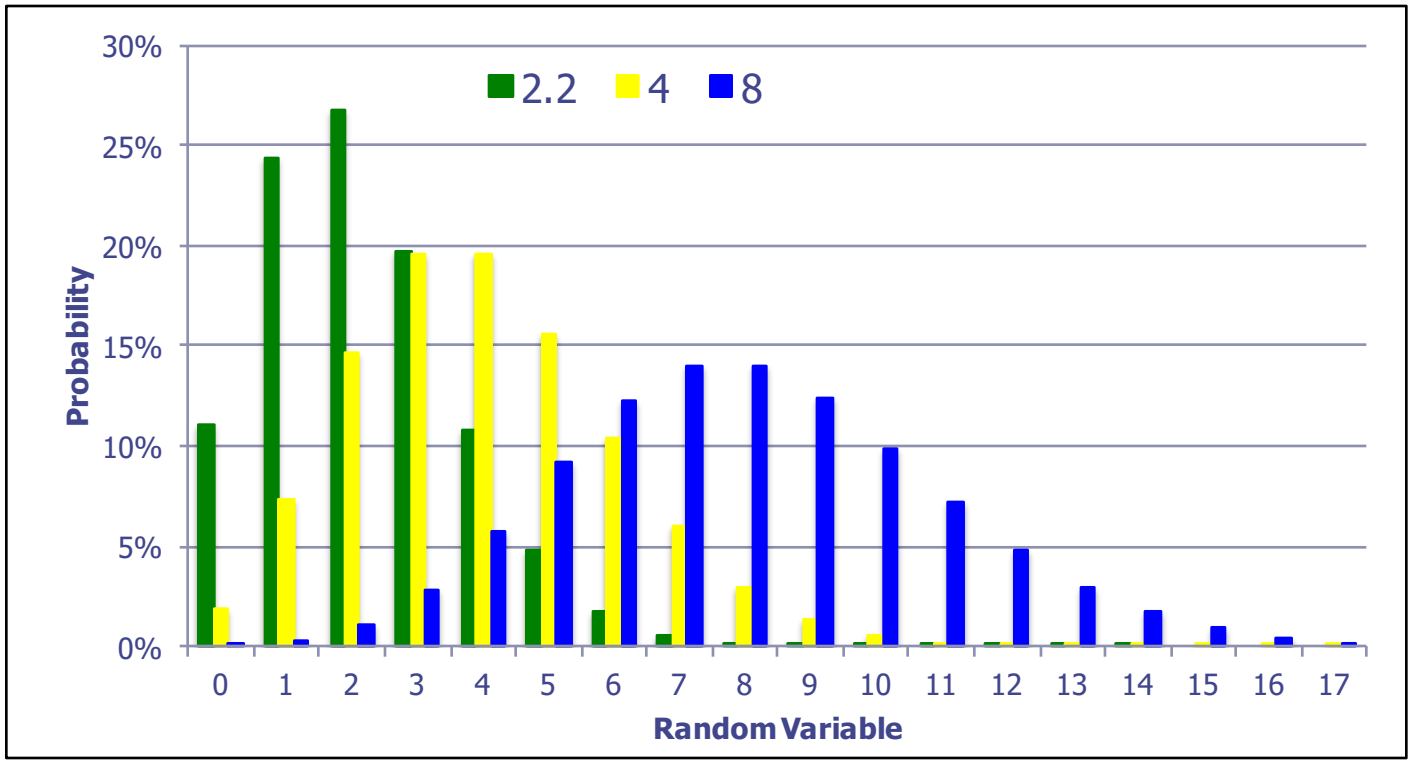


# Poisson Distribution

- Poisson ~P(λ)
  - Probability of x events occurring w/in a time period
  - Mean = Variance = λ
- In Spreadsheets:
  - $p(x_0)$ = POISSON($x_0$,λ,0)
  - $F(x_0)$ = POISSON($x_0$,λ,1)

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

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




Poisson Tables (partial)

- Columns: λ
- 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 | |

# 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!



MIT Center for Transportation & Logistics

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