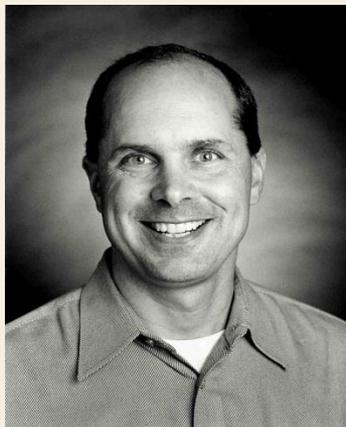


# Ocean Transportation Reliability: Myths, Realities and Impacts



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# Background

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- Fall 2010 – a global manufacturer asked us,  
    **“How reliable is my ocean shipping?”**
- Created the MIT Global Transportation Reliability Initiative
  - Dr. Bruce Arntzen, Dr. Chris Caplice, Dr. Basak Kalkanci, Lita Das (PhD candidate)
- Main Activities 2010 – 2013
  - Analysis of transactional data from multiple firms
  - Held annual invitation-only Roundtables
- Key Research Questions
  1. How does the perceptions of ocean transport reliability match the reality?
  2. When should a shipper care about reliability and when should it not?

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# Six Myths of Ocean Reliability

# Myth 1: There is a single definition of reliability

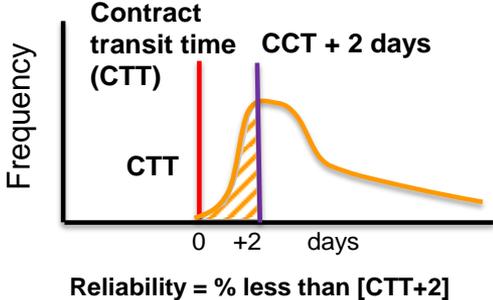
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## Two dimensions of reliability

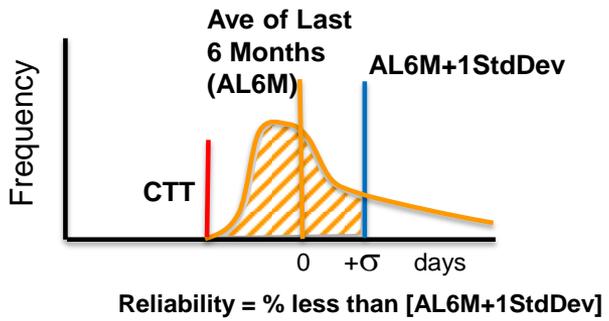
- Credibility
  - Did the carrier do what they were supposed to do?
  - Reserve slots as agreed to? (Rejections / Bumping)
  - Stop at all ports agreed to? (Skipping)
  - Load all containers committed? (Cut & Run)
- Schedule Consistency
  - How close were they to their quoted schedule?
  - How consistent is their actual transit time?

# Myth 1: There is a single definition of reliability (cont.'d)

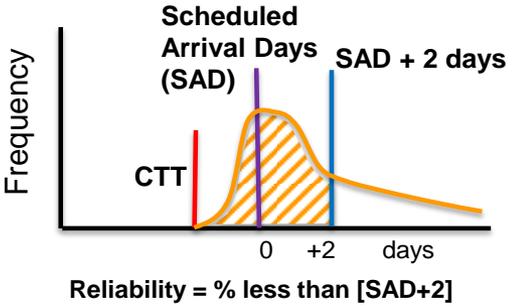
Compare actual transit time to the contract.



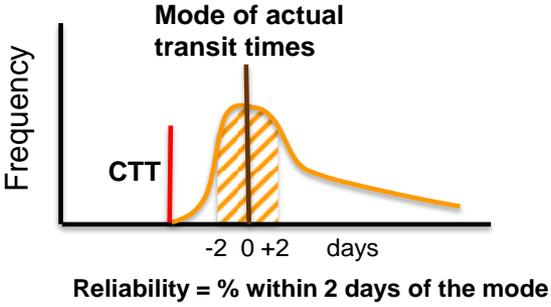
Compare actual transit time to the average of the last 6 months.



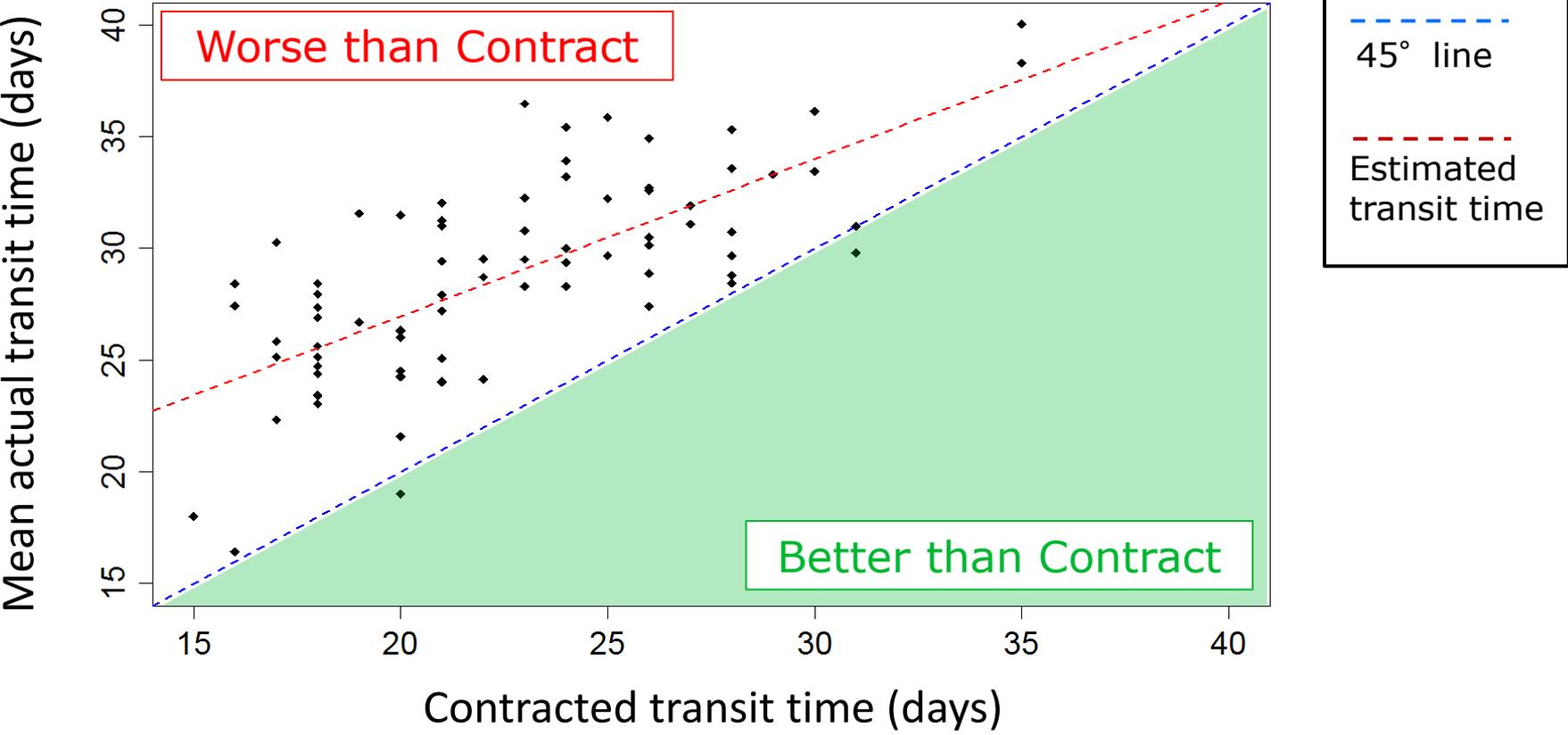
Compare actual transit time to the published ship schedule.



Measure the “tightness” of the distribution of transit times.

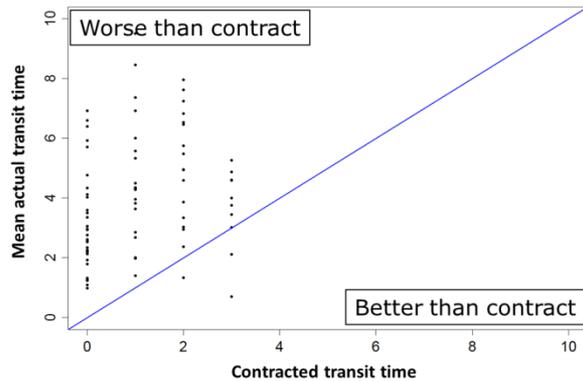


# Myth 2: Contract reliability in procurement and operations match

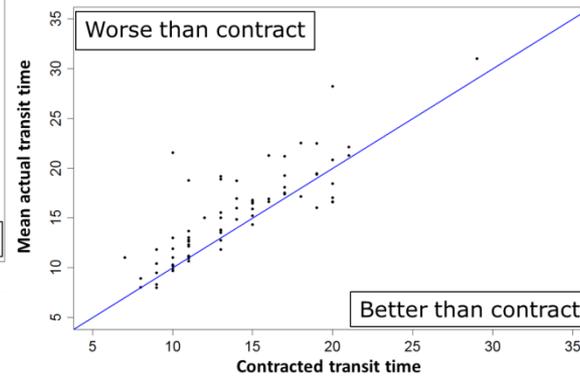


# Myth 2: Contract reliability in procurement and operations match (cont.'d)

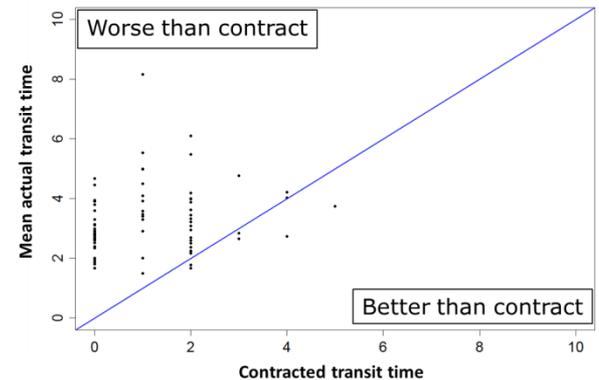
While estimates of the port-to-port transit times are fairly accurate, the port throughput estimates are not.



Origin Port Throughput



Port-to-Port Transit Time



Destination Port Throughput

# Myth 3: Port-to-port performance is a good measure of end-to-end reliability

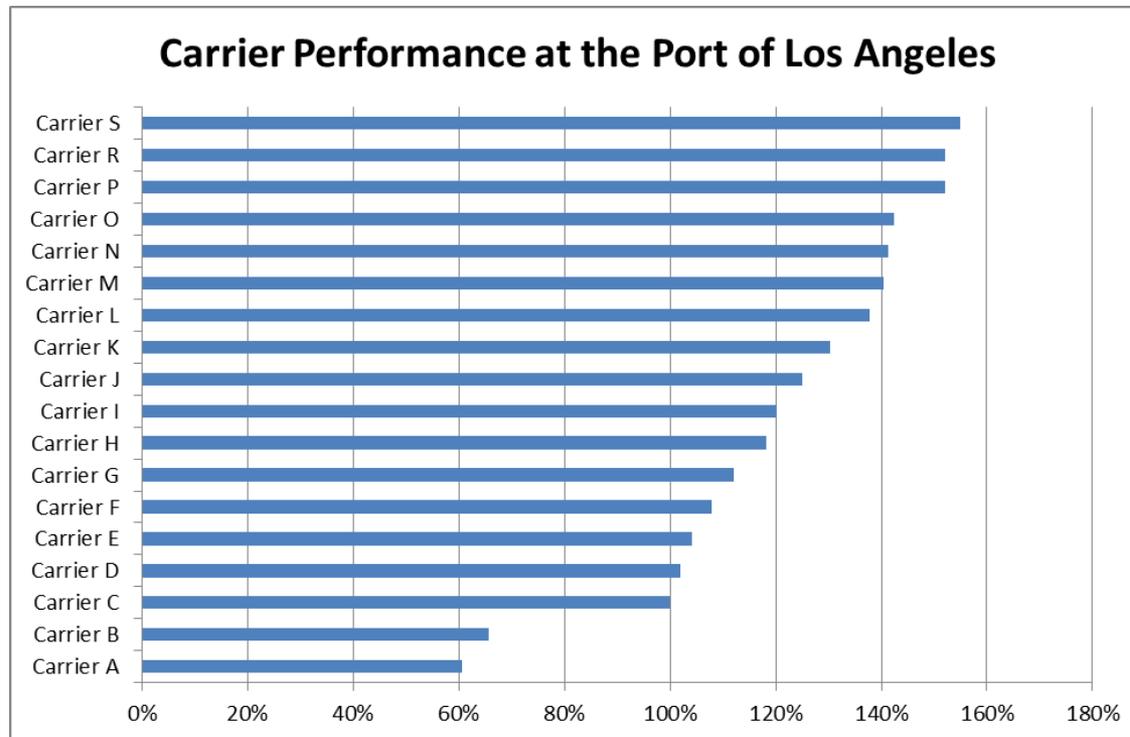
- The port-to-port segment is the most stable leg
- There is significant dwell time in the ports (approximately 3-4 days)
- Landside legs can have high variability

	Origin Landside Transit	Origin Port Dwell	Ocean Transit	Destination Port Dwell	Destination Landside Transit
APAC to North America	1.2	0.9	0.4	1.0	0.8
South America to North America	1.3	0.8	0.2	0.8	0.9
Europe to North America	0.7	0.7	0.3	0.7	0.7
North America to Europe	0.8	0.9	0.5	0.8	1.3

Coefficient of Variation in Each Segment (Std. Dev. / Average)

# Myth 3: Port-to-port performance is a good measure of end-to-end reliability (cont.'d)

- Analysis of >71,000 container shipments showed that different carriers have radically different dwell times at the same port
- Port throughput time decreases when (1) more terminals are used or (2) when the carrier has a dedicated terminal.



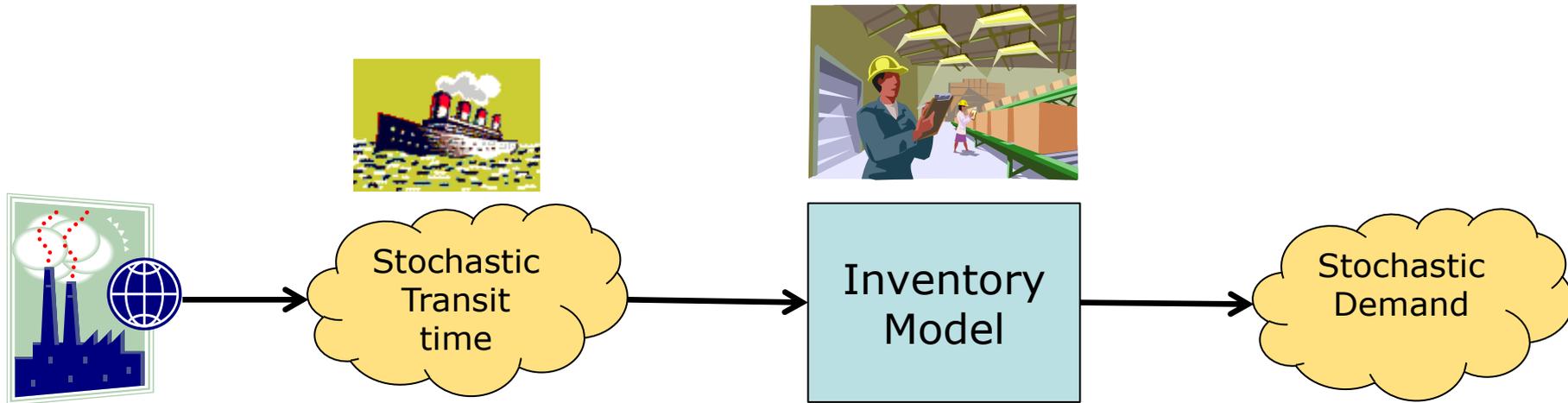
Efficiency of a carrier at handling containers (keeping other factors constant)

# Myth 4: Transit time data are used effectively in inventory planning

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- Few shippers collect lead-time reliability data
  - Data doesn't feed into their ERP systems to automatically
  - Most (all) ERP systems only accept a single value for lead-time, not a range of values or even a standard deviation
- Inventory level is usually based on worst rather than average case
- Business case for increased reliability is not clear
  - Transportation managers have difficulty selling senior management on the value of decreasing transit variability
  - The impact is not consistent between commodities or trade-lanes

# Myth 5: Reducing average lead time is more important than reducing variability



- Shipment data from 2 retailers to quantify the value of reducing lead-time versus variability (>250,000 containers)
- Five scenarios were tested:
  - Reduction of the average transit time by 3,5 or 7 days
  - Reduction of the variability (standard deviation) of the transit time by 1 or 3 days

# Myth 5: Reducing average lead time is more important than reducing variability (cont'd)

## Percent decrease in inventory

	3 day reduction on average	5 days reduction on average	7 days reduction on average	1 day reduction in standard deviation	3 days reduction in standard deviation
Average	3.5%	5.9%	8%	2.6%	7.7%
Min	0.5%	2.0%	4.9%	0%	5.2%
Max	8.1%	9.6%	9.9%	9.2%	10.9%

- Reducing variability helps significantly (schedule consistency and punctuality are important!)
- Reducing average transit time pays off more if the transit time of the lane is short and consistent
- Reducing variability pays off more if the transit time of the lane is short, but variable

# Myth 6: Slow steaming is bad for supply chains

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- Federal Maritime Commission inquired various carriers and shippers on the impacts of slow steaming in 2011
  - National Retail Federation: “Supply chain days are extended while cost savings are not passed on the shippers”
  - Maersk, MSCU, and OOCL: “Although the slow steaming increases the transit times, it also improves schedule reliability since the carriers have more buffer time between port calls”

# Myth 6: Slow steaming is bad for supply chains (cont.'d)

Origin / Destination	Mean Transit Time (2008)	Standard Deviation of Transit Time (2008)	Mean Transit Time (2011)	Standard Deviation of Transit Time (2011)
HONG KONG-SAVANNAH	25.6	1.7	27.7	1
HONG KONG-HOUSTON	21	1	25.8	0.8
CHIWAN-LONG BEACH	12.8	0.9	14.5	0.5

- We find lanes where transit times increased, but standard deviation is *decreased* after slow steaming

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# When Should Shippers Care About Ocean Unreliability?

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# The Problem

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- Ocean transit time is a varied dimension
  - Central tendency (average, expected, median, etc.)
  - Dispersion (variance, range, etc.)
  - Shape of the distribution (tails matter)
- The impact of the average transit time is well understood – but not the variability
- Business case also depends on the value of the goods – or the trade-off of shortage/holding costs

# Current State of Practice

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- Most common approach (Policy I): Ignore It!
  - Systems typically allow only one transit time value
  - Single time input per trade lane
- More sophisticated approach (Policy II):  
Incorporate variability
  - Include a variance as well as a mean
  - Determine the joint demand under uncertain transit time (Hadley-Whitin equation)
  - Apply this to a Normal distribution to set safety stock
- Optimal Approach
  - Calculate the demand over a variable lead time
  - Use actual (or historical) demand

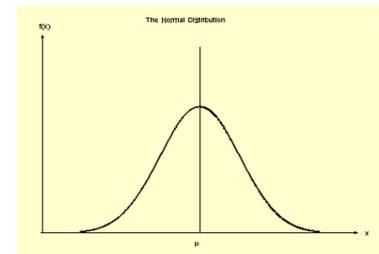
# Incorporating Variability (Policy II)

- Most commonly taught method to incorporate variability is the Hadley-Whitin (1963) equation

$$E(X_{DoLT}) = E(L)E(D)$$

$$\sigma_{DoLT} = \sqrt{E(L)\sigma_D^2 + (E(D))^2 \sigma_L^2}$$

- Where:
  - $E(L)$  = Average lead time
  - $\sigma^2(L)$  = Variability of lead time
  - $E(D)$  = Average demand during one time period
  - $\sigma^2(D)$  = Variability of demand during one time period
- This is then applied to a Normal distribution



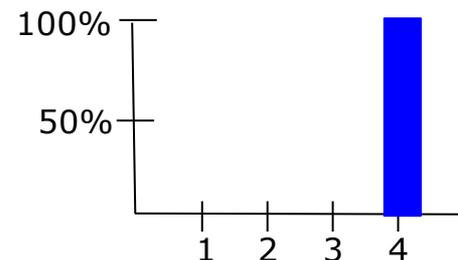
# But, Policy II may not Work as Planned

- What is the Expected Demand during lead time when overall demand is distributed Normally  $\sim (100,10)$  per week?

Recall that Expected Demand =  $X_{\text{DoLT}} + k \sigma_{\text{DoLT}}$

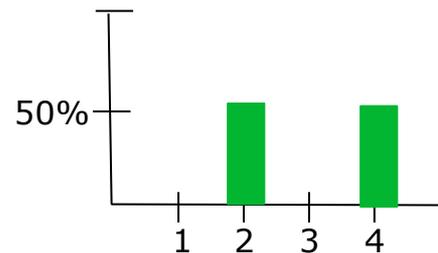
- **Case 1: Lead time = 4 weeks – with no variability**

- $X_{\text{DoLT}} = (100 \text{ u/wk})(4 \text{ wk}) = 400$
- $k = 1.645$  (assumed)
- $\sigma_{\text{DoLT}} = (10 \text{ units/wk})(\text{sqrt}(4)) = 20$
- Exp Demand =  $4(100) + 1.645(20) = \mathbf{433 \text{ units}}$



- **Case 2: Lead time = 2 weeks ½ the time & 4 weeks the rest**

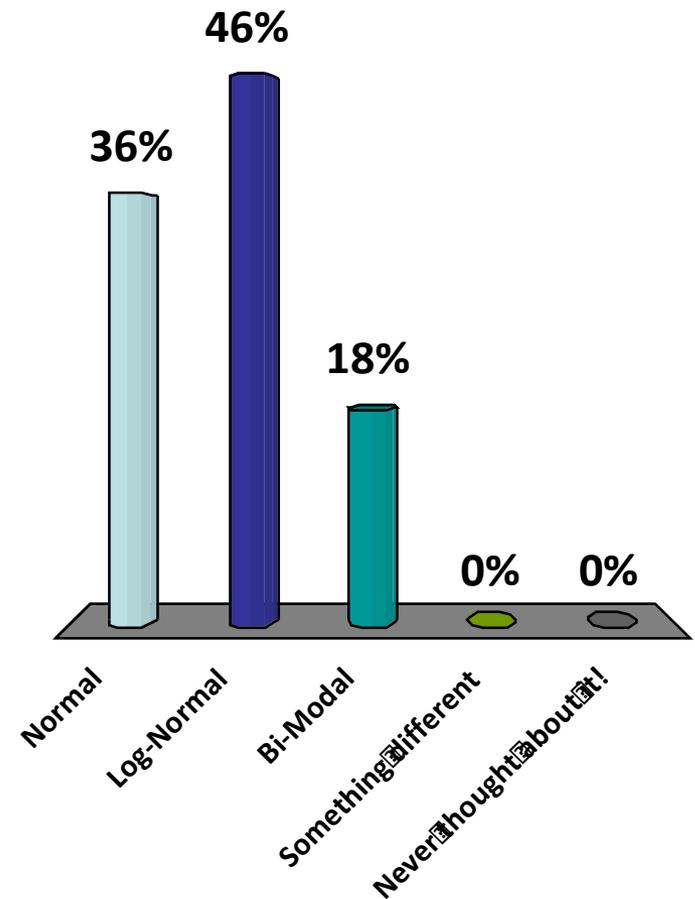
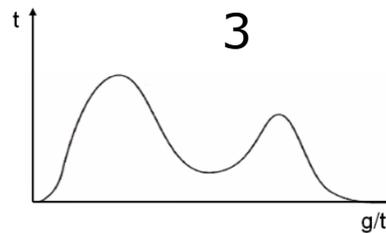
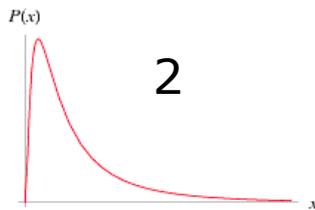
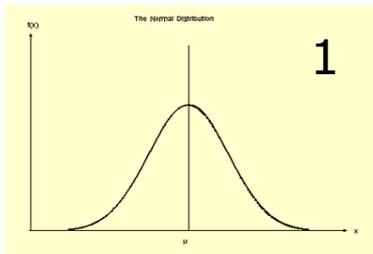
- $X_{\text{DoLT}} = (100 \text{ u/wk})(3 \text{ wk}) = 300$
- $k = 1.645$  (assumed)
- $\sigma_{\text{DoLT}} = \text{sqrt}[(3)(10)^2 + (100)^2(1)] = 101.5$
- Exp Demand =  $3(100) + 1.645(101.5) = \mathbf{467 \text{ units}}$



**Why do we need more inventory for Case 2?**

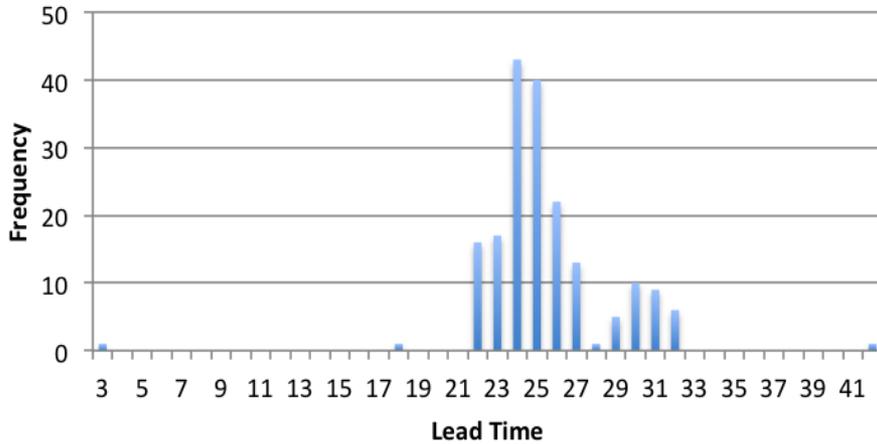
# Roundtable Survey: Which Figure Best Characterizes Your Typical Ocean Transit Time Distribution?

1. Normal
2. Log-Normal
3. Bi-Modal
4. Something different
5. Never thought about it!

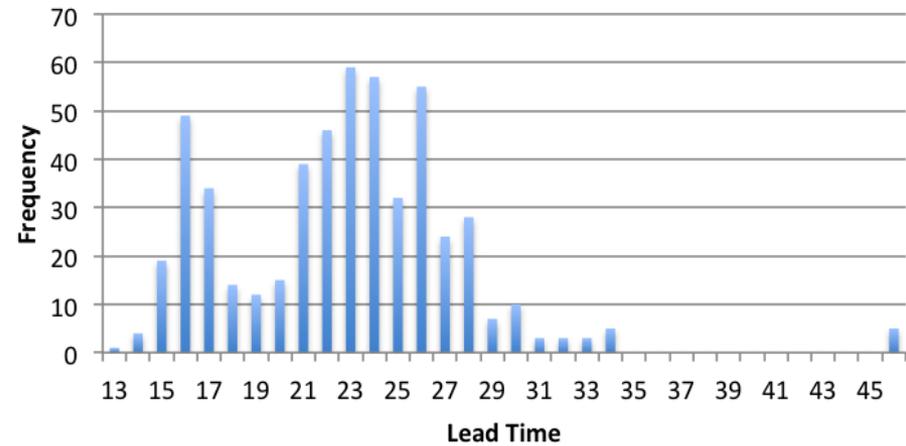


# Are ocean transit times normally distributed?

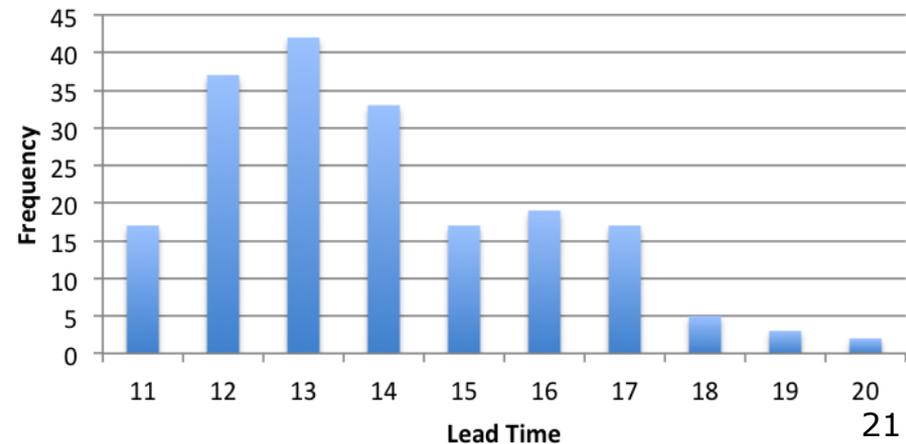
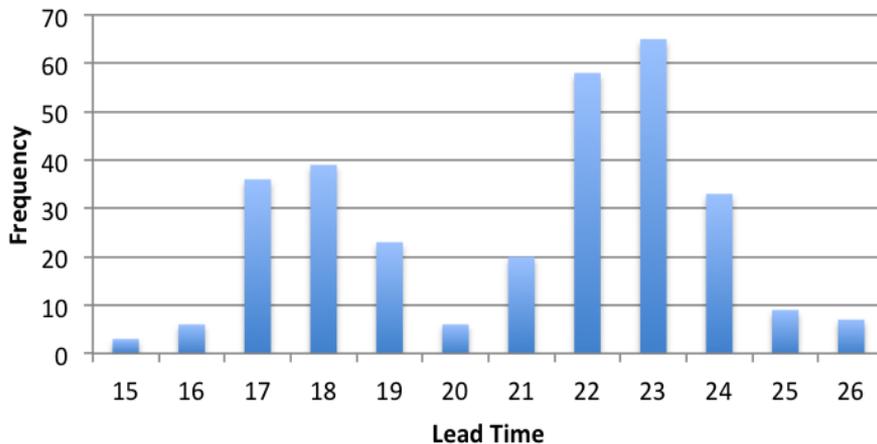
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Transit time distributions are often multi-modal and/or have long right tails.

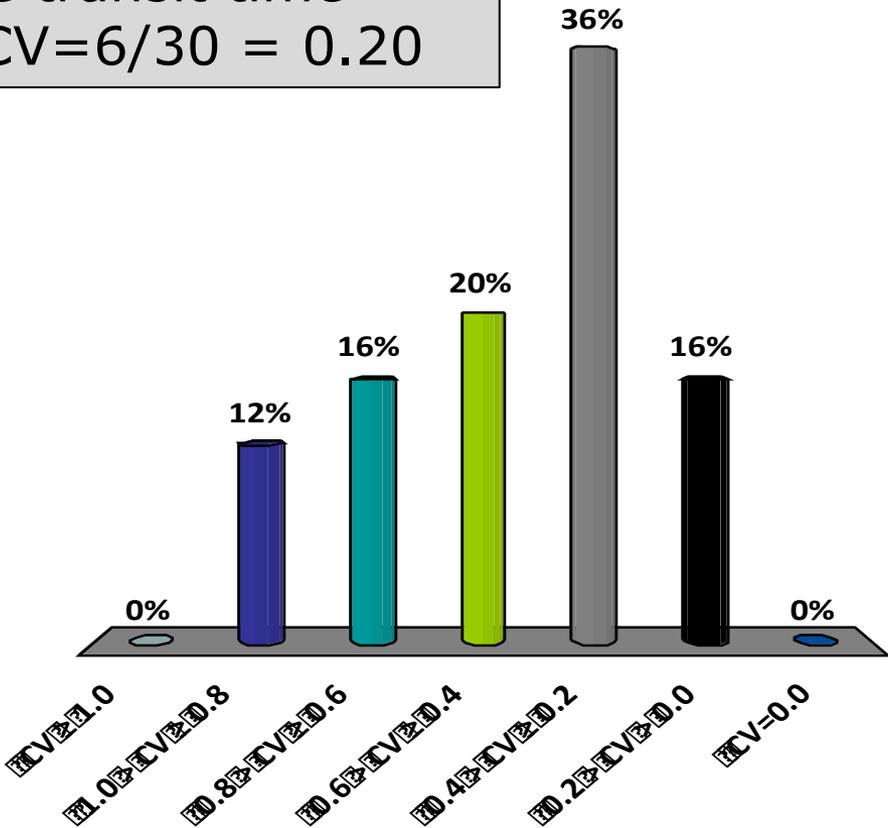


# Roundtable Survey:

## How consistent is your door-door ocean transit?

Coefficient of Variation (CV) = Stnd Dev / Mean  
For example, if on average transit time  
= 30 days +/- 6 days then  $CV = 6/30 = 0.20$

- 1.  $CV \geq 1.0$
- 2.  $1.0 > CV \geq 0.8$
- 3.  $0.8 > CV \geq 0.6$
- 4.  $0.6 > CV \geq 0.4$
- 5.  $0.4 > CV \geq 0.2$
- 6.  $0.2 > CV > 0.0$
- 7.  $CV = 0.0$



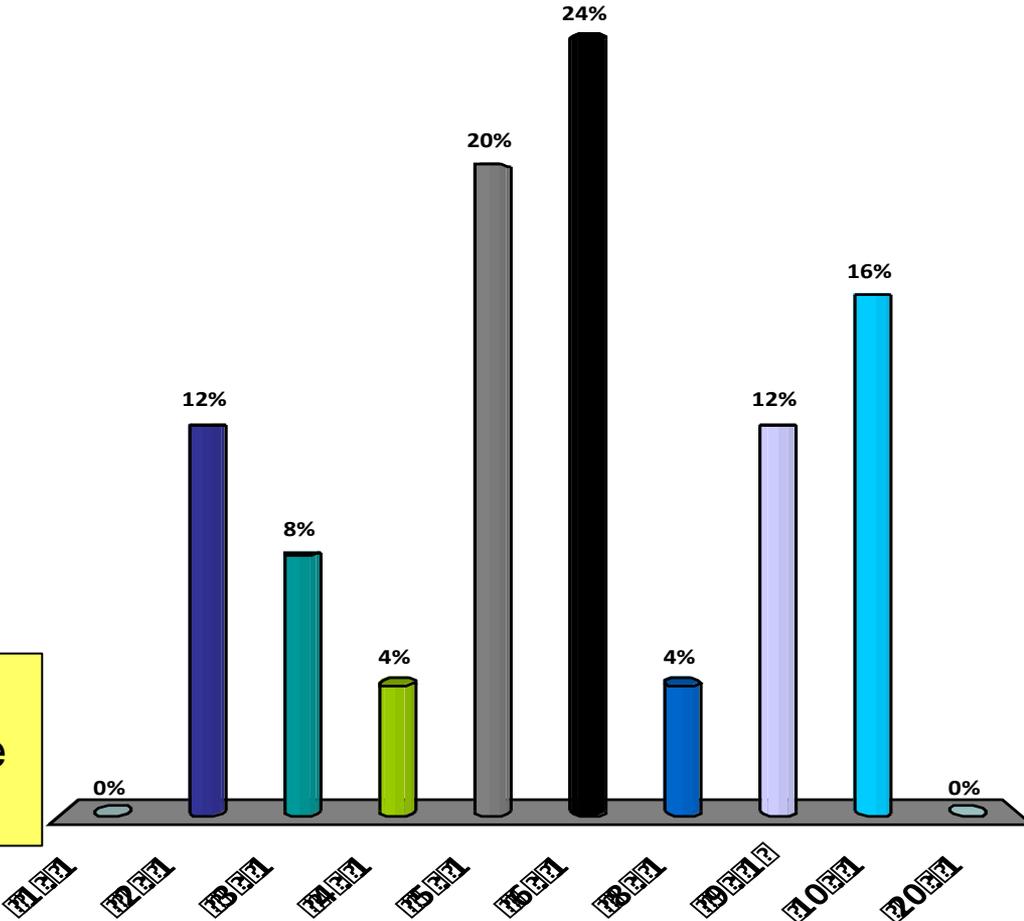
# Roundtable Survey:

## What is Your Trade-off Between Holding & Shortage Costs?

The cost of X days of inventory is equal to Y days of delay in shipment delivery.

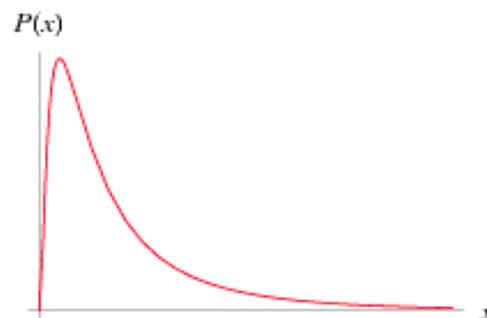
1.	1 : 1	CR = .50
2.	2 : 1	CR = .66
3.	3 : 1	CR = .75
4.	4 : 1	CR = .80
5.	5 : 1	CR = .83
6.	6 : 1	CR = .85
7.	8 : 1	CR = .88
8.	9 : 1	CR = .90
9.	10 : 1	CR = .92
10.	20 : 1	CR = .95

Critical Ratio is a measure of service level. It is the balance between overage and underage costs and is  $0 < CR < 1$ .

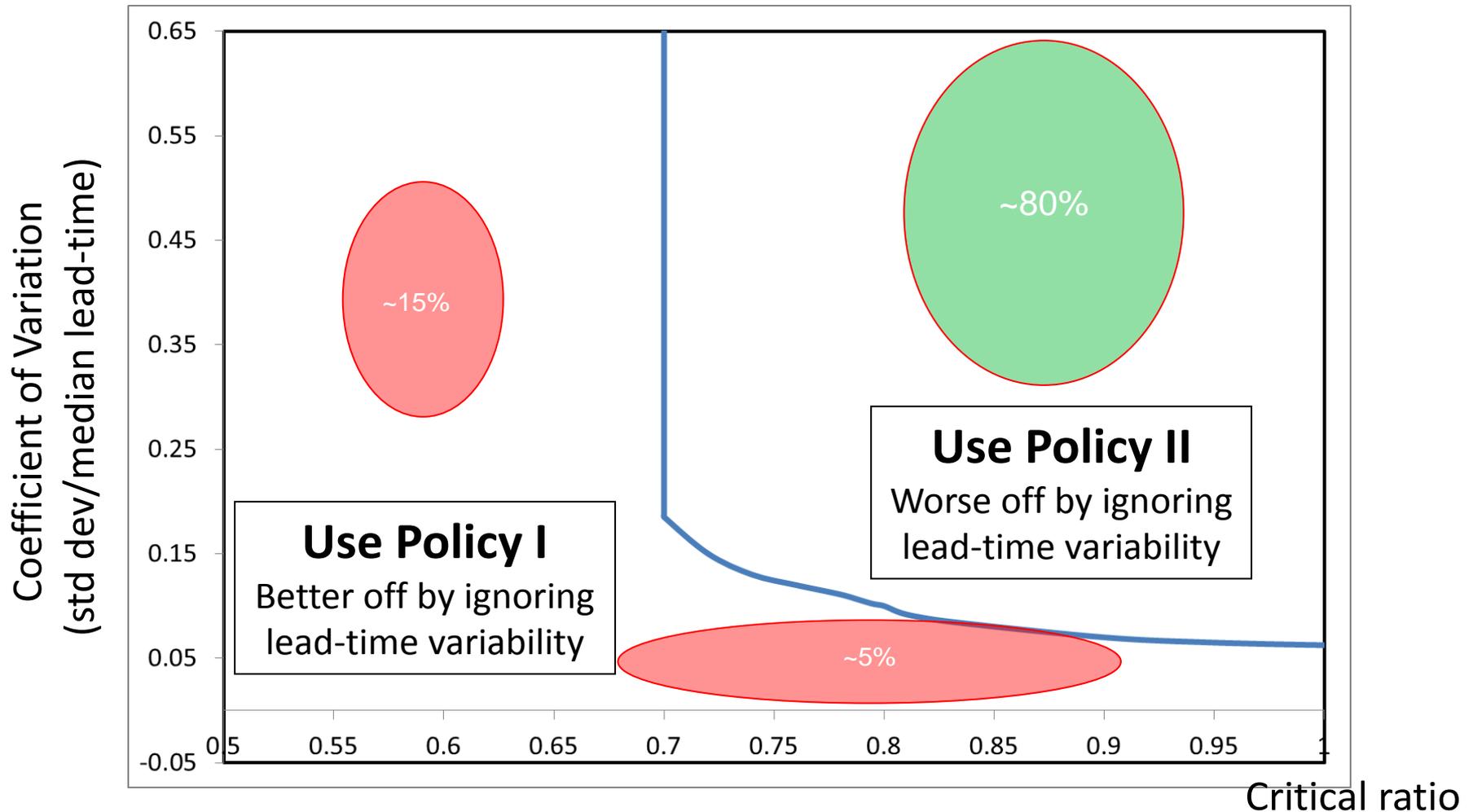


# Comparing Policy I and II with Optimal

- How do different inventory policies compare to the optimal policy under different lead-time distributions?
- The comparison depends on:
  - Transit time distribution
  - Trade-off between underage and overage costs
  - Customer demand distribution
- Ran scenarios comparing how Policy I and II compares to the Optimal policy for:
  - A range of critical ratios
  - Normally distributed demand per day
  - **Lognormal transit times**

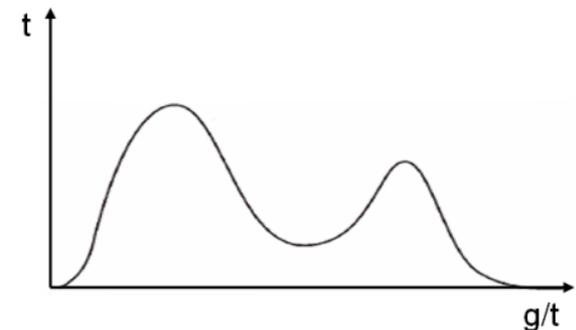


# Comparing Policy I and II with Optimal: Lognormal Distribution (cont.'d)



# Comparing Policy I and II with Optimal: Bimodal Distribution

- Bimodal transit times can occur due to:
  - Bumping of freight at the origin port
  - Weekend delays in offloading freight at the destination port
  - Multiple carriers handling a single trade-lane
  - Slow steaming (flexibility to adjust speed)
- Ran scenarios comparing how Policy I and II compares to the Optimal policy for:
  - A range of critical ratios
  - Normally distributed demand per day
  - **Bimodal transit times of varying levels**
- Initial Results
  - Policy II is always better than Policy I when  $CR \geq 0.50$
  - Policy II deteriorates as the distance between modes increases



# Key Take-Aways

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- Management by anecdote versus analysis
- Perverse effects of slow-steaming
- Different legs have differing levels of reliability – and port-to-port is usually the most stable
- Ocean transit time distributions tend to be strange – bimodal or with a long right tail
- Business case for reducing reliability is not always clear – but seems to depend on the play between:
  - Transit time variability (Coefficient of Variation)
  - Firm's overage/underage cost trade-off (Critical Ratio)

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# Thank you for your time

We will be happy to take any questions now

For more information please email:

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April 18, 2013 – Supply Chain Analytics Roundtable  
[http://ctl.mit.edu/events/supply\\_chain\\_analytics\\_roundtable\\_418](http://ctl.mit.edu/events/supply_chain_analytics_roundtable_418)

June 11-14, 2013 - Supply Chain Management:  
Driving Strategic Advantage – Executive Education  
Course <http://ctl.mit.edu/events/execed-course>

*Questions about the CTL Supply Chain Exchange?*

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