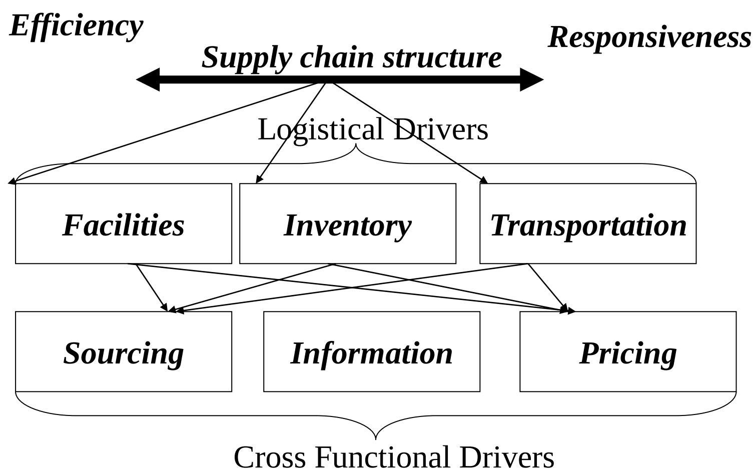
Drivers of Supply Chain Performance



1

Linking Financial Performance to Supply Chain Metrics

Tiffany vs. BlueNile

2

Linking Financial Performance to SC Metrics

- What financial metrics are influenced by supply chain decisions?
- What supply chain drivers influence different financial measures?
- Depending on the strategic position of the company, different supply chain metrics are important to track and improve financial performance.
- Role of facilities – identify the broad network structure

3

Tiffany vs. BlueNile

4

	A	B
Total Revenues	4,800.6	4,442.1
Cost of Goods sold	3,877.1	1,631.1
Gross Profit	923.5	2,811.0
SG&A	763.0	2,020.7
Operating Income	160.5	790.3
Interest Expenses	(0.9)	39.7
Other Loss (income)	0.2	7.1
Income before income taxes	161.1	743.5
Income taxes	55.8	157.1
Net Income	105.3	586.4
Assets	-	
Cash and cash equilvalents	865.4	855.3
Net Receivables	46.5	245.4
Inventories	463.8	2,428.0
Prepaid expenses and other	15.9	230.8
Total current assets	1,391.5	3,759.5
Property, Plant and Equipment	105.3	1,026.7
Goodwill	0.8	
Other Assests	76.5	546.8
Total Assets	1,574.1	5,333.0
Liabilities and Stockholder Equity	-	
Accounts Payable	1,342.5	513.4
Short-term Debt	3.2	204.7
Total current liability	1,345.8	718.1
Long term debt	43.8	1,484.0
Total liabilities	1,389.6	2,202.1
Stockholder Equity	184.6	3,130.9

Financial Statements of Blue Nile and Tiffany: (Their units are different: One is in Millions and the other is in 100,000.)

Q1: Which one is Blue Nile? A or B Why?

Q2: How Tiffany makes money? How Blue Nile makes money?

5

Tiffany vs. Blue Niles

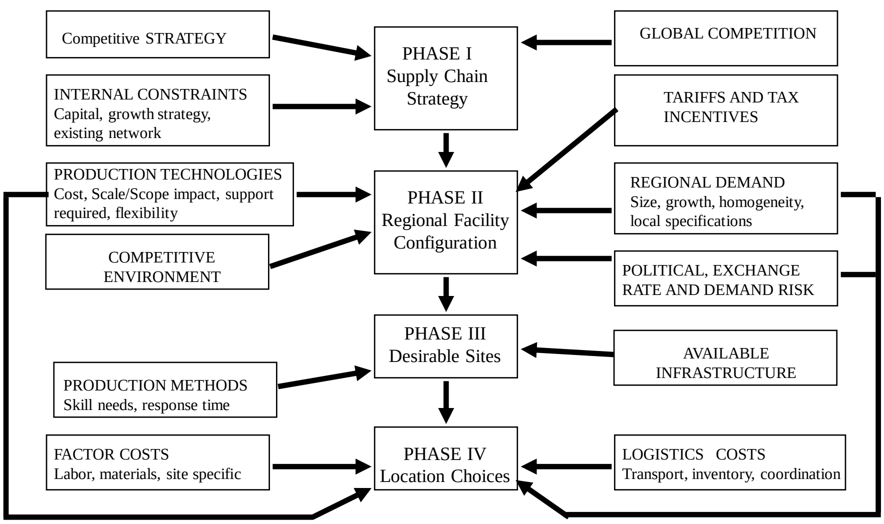
6

Designing the Supply Chain Network

Facility Decisions

7

A Framework for Network Design Decisions



8

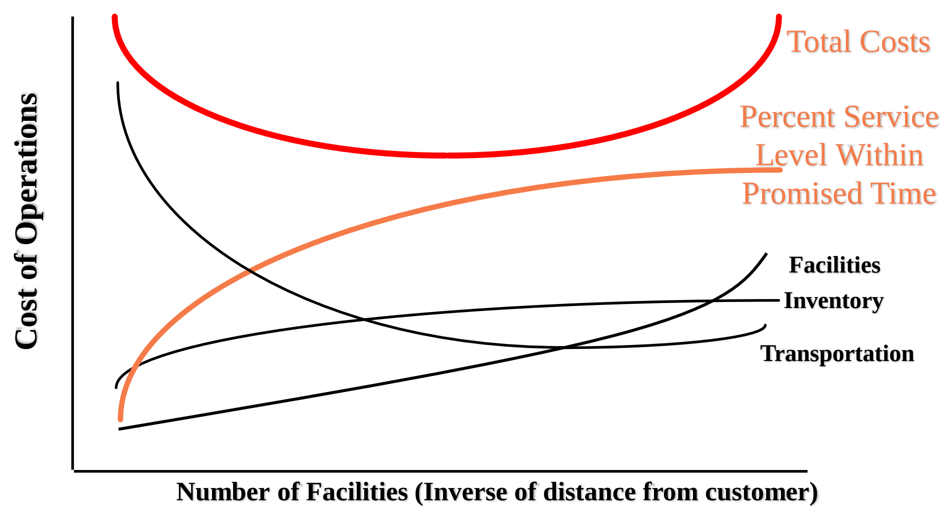
Phase I: Distribution Network Design

Distribution Network

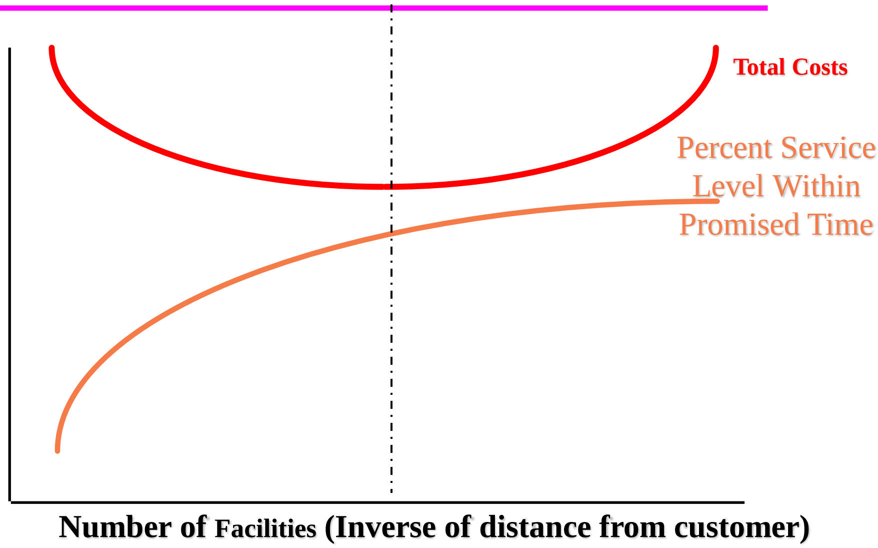
Customer needs:
- Response time
- Product variety
- Product availability
- Customer experience
- Order visibility
- Returnability

Cost of meeting needs
- Inventories
- Transportation
- Facilities & handling
- Information

Service and Cost Build-up



Service and Cost Build-up



11

Potential Distribution Networks

- Manufacturer storage with drop ship
- Manufacturer storage with merge in-transit
- Distributor storage with package delivery
- Distributor storage with last-mile delivery
- Manufacturer/distributor storage with local pickup
- Local storage with pickup (Retail Stores)

12

Relative Strengths and Weaknesses of Delivery Networks

	Manu-facturer Storage & Direct Shipping	Manu-facturer Storage & In-Transit Merge	Manu-facturer Storage & Pickup	Distributor Storage & Package Carrier Delivery	Distributor Storage & Last Mile Delivery	Retail Storage & Customer Pickup
Response Time						
Product Variety						
Product Availability						
Customer Experience						
Order Visibility						
Returnability						
Inventory						
Transportation						
Facility & Handling						
Information						

Linking Product Characteristics and Customer Preferences to Network Design

	Manu-facturer Storage & Direct Shipping	Manu-facturer Storage & In-Transit Merge	Manu-facturer Storage & Pickup	Distributor Storage & Package Carrier Delivery	Distributor Storage & Last Mile Delivery	Retail Storage & Customer Pickup
High demand product						
Med. demand product						
Low demand product						
Many product sources						
High product value						
Quick desired response						
High product variety						
Low customer effort						

Network Design Decisions

PHASE I — Supply Chain Strategy ⇒ Broad Structure

↓

PHASE II — **Obtain Regional Facility Configuration**

↓

PHASE III — Select Suitable Sites

↓

PHASE IV — Decide Facility Location and Capacity Allocation

Ongoing Decision: Market and supply allocation

Phase II: Regional Facility Configuration

- Which regions should have facilities?
- Key Factors:
  - Regional demand configuration
  - Taxes and tariffs
  - Fixed facility cost (economies of scale)
  - Transportation cost
  - Production cost
  - Inventory cost
  - Coordination cost

Network Design Decisions

PHASE I — Supply Chain Strategy ⇒ Broad Structure

↓

PHASE II — Obtain Regional Facility Configuration

↓

PHASE III — **Select Suitable Sites** -- Gravity model

↓

PHASE IV — Decide Facility Location and Capacity Allocation

Ongoing Decision: Market and supply allocation

Phase III: Selecting Suitable Sites Gravity Methods for Location

- Model
  - x,y: Warehouse Coordinates (TBD)
  - x_n, y_n: Coordinates of location n
  - d_n: Distance to/from location n
  - F_n: Tonnage (cost/ton-mile to/from location n)
  - D_n: Tons to/from location n

Example: Steel Appliances

Ton-Mile Center Solution

$$d_n = \sqrt{(x - x_n)^2 + (y - y_n)^2}$$

$$Min \quad \sum_{n=1}^{k} d_n D_n F_n$$

Network Design Decisions

PHASE I	Supply Chain Strategy ⇒ Broad Structure
PHASE II	Obtain Regional Facility Configuration
PHASE III	Select Suitable Sites
PHASE IV	**Decide Facility Location and Capacity Allocation**

Ongoing Decision: Market and supply allocation

Facility Location, Capacity and Demand Allocation

- Typical issues when rationalizing supply chain network, e.g., after a merger
  - *Facility location*: Which plants to keep open?
  - *Capacity allocation*: What capacity to assign to each plant?
  - ***Demand allocation*: Which markets to assign to each plant?**

Which Markets to Assign to Each Plant? The Demand Allocation Model

- Which market is served by which plant?
- Which supply sources are used by a plant?

x_{ij} = *Quantity shipped from plant site i to customer j*

$$Min \sum_{i=1}^{n} \sum_{j=1}^{m} c_{ij} x_{ij}$$

$$s.t.$$

$$\sum_{i=1}^{n} x_{ij} = D_j$$

$$\sum_{j=1}^{m} x_{ij} \leq K_i$$

$$x_{ij} \geq 0$$

Capacity Investment Strategies

- Speculative Strategy
  - Single sourcing
- Hedging Strategy
  - Match revenue and cost exposure
- Flexible Strategy
  - Excess total capacity in multiple plants
  - Flexible technologies

Demand Forecasting in a Supply Chain

1. Characteristics of forecasting for a supply chain
2. Components of a demand forecast
3. Forecast demand in a supply chain given historical demand data using time-series methodologies
4. Analyze demand forecasts to estimate forecast error

23

Characteristics of Forecasts

1. Forecasts are always **inaccurate** and should thus include both the expected value of the forecast and a measure of **forecast error**
2. **Long-term** forecasts are usually **less accurate** than short-term forecasts
3. **Aggregate** forecasts are usually **more accurate** than disaggregate forecasts
4. In general, **the farther up the supply chain** a company is, **the greater is the distortion** of information it receives

24

Three steps of “range” forecasting

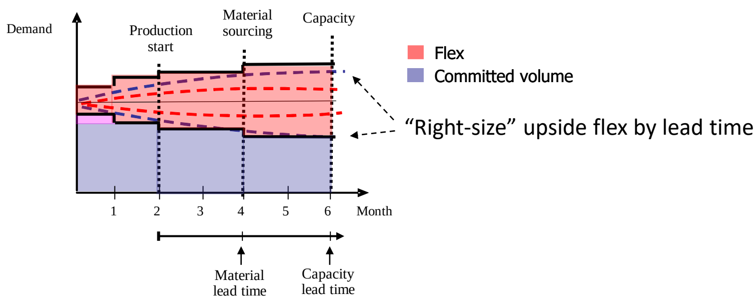
(incorporating uncertainty in core planning processes)

1. What is the range of potential future circumstances?
2. How is our operating and financial performance exposed across that range?
   - Too little supply: Lost sales and customer satisfaction
   - Too much supply: Excess capacity, inventory and other liabilities
3. How can we proactively plan and manage our business to deliver the best possible operating and financial performance?
   - “Supply side”: Assets, capacity, production…
   - “Demand side”: Sales, marketing, partners…

Source: Blake Johnson from Stanford University

25

Range planning: Financial analogies



Financial instrument analogy:
- Blue is futures contract (fixed quantity)
- Pink is options contract (flex quantity)

Insurance analogy:
- Blue is “demand insurance” buyer provides to supplier
- Pink is “availability insurance” supplier provides to buyer

Source: Blake Johnson from Stanford University

26

Components and Methods

1. Qualitative
   - Primarily subjective
   - Rely on judgment
2. **Time Series**
   - Use historical demand only
   - Best with stable demand
3. **Causal**
   - Relationship between demand and some other factor
4. Simulation
   - Imitate consumer choices that give rise to demand

27

Components of an Observation

Observed demand (*O*) =systematic component (*S*)
+ random component (*R*)

- Systematic component – expected value of demand
  - ***Level*** (current deseasonalized demand)
  - ***Trend*** (growth or decline in demand)
  - ***Seasonality*** (predictable seasonal fluctuation)
- *Random component* – part of forecast that deviates from systematic part
- *Forecast error* – difference between forecast and actual demand

28

Moving Average

- Used when demand has **no observable trend or seasonality**

Systematic component of demand = level

- The level in period t is the average demand over the last N periods

$$L_t = (D_t + D_{t-1} + \ldots + D_{t-N+1}) / \mathrm{N}$$

$$F_{t+1} = L_t \quad \text{and} \quad F_{t+n} = L_t$$

- After observing the demand for period $t + 1$, revise the estimates

$$L_{t+1} = (D_{t+1} + D_t + \ldots + D_{t-N+2}) / N, \quad F_{t+2} = L_{t+1}$$

29

Moving Average Example

- A supermarket has experienced weekly demand of eggs of $D_1 = 1974$, $D_2 = 1919$, $D_3 = 1731$, and $D_4 = 1668$ over the first four weeks
  - Forecast demand for Week 5 using a four-period moving average?
  - What is the forecast error if demand in Week 5 turns out to be 1895?

30

Moving Average Example

$L_4 = (D_4 + D_3 + D_2 + D_1)/4$

- Forecast demand for Period 5

  $F_5 = L_4$

- Error if demand in Period 5 = 1895

  $E_5 = D_5 - F_5$

- Revised demand → becomes the forecast for week 6

  $L_5 = (D_5 + D_4 + D_3 + D_2)/4$

31

Moving Average Exercise I

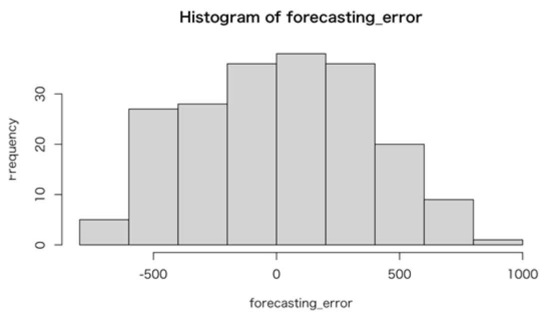
- What is the forecast demand for week 301 using the moving average of past 4 weeks?

- [challenging] Suppose that the price of a cartoon of eggs is $4, and the cost is $0.8. You order the eggs once a week, and throw away all leftovers, i.e., salvage value of $0. Then, right before week 301, without knowing the actual demand, how many cartoons of eggs you will order?

32

Moving Average Exercise

- The distribution of the forecast → point forecast + forecasting errors



33

Moving Average Exercise II

- Suppose that you don't do the moving average forecasting. Instead, you follow the approach we learned during the last session, i.e., looking at the histogram and decide the same order quantity every week. Use the dataset from week 301 to week 500. In this case, what is the order quantity?

- [Challenging] Compared to the above, what is the daily value of moving average forecasting system?

34

Simple Exponential Smoothing

- Used when demand has **no observable trend or seasonality**

Systematic component of demand = level

36

Simple Exponential Smoothing

Current forecast $F_{t+1} = L_t$

Revised forecast using smoothing constant $(0 < \alpha < 1)$

$$L_{t+1} = \alpha D_{t+1} + (1-\alpha) L_t$$

Thus

$$L_{t+1} = \sum_{n=0}^{t-1} \alpha (1-\alpha)^n D_{t+1-n} + (1-\alpha)^t D_1$$

(Use L_0 as the average of the demand data)

37

Simple Exponential Smoothing

- Supermarket Eggs data

  What is the forecast of week 101? (Use L_0 <- D_1)

  what is the forecasting error of week 101?

  what is the forecast of week 102 (use $\alpha=0.2$)?

38

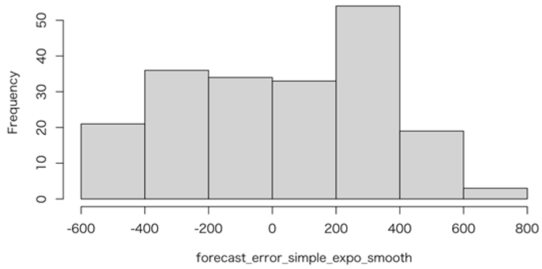
Simple Exponential Smoothing Exercise I

- What is the forecast demand for week 301 using simple exponential smoothing?
- [challenging] Suppose that the price of a cartoon of eggs is $4, and the cost is $0.8. You order the eggs once a week, and throw away all leftovers, i.e., salvage value of $0. Then, right before week 301, without knowing the actual demand, how many cartoons of eggs you will order, using the simple exponential smoothing model?

39

Simple ES Exercise

- The distribution of the forecast → point forecast + forecasting errors



40

Simple ES Exercise II

- Compared to the moving average model, what is the daily value of simple exponential smoothing forecasting system with $\alpha=0.2$?

41

Trend-Corrected Exponential Smoothing (Holt's Model)

- Obtain initial estimate of level and trend by running a linear regression, etc., e.g.

$$D_t = at + b$$

Estimate a and b

- The forecast for future periods is

$$F_{t+1} = L_t + T_t \quad \text{and} \quad F_{t+n} = L_t + nT_t$$

- Revised estimates for Period t

$$L_{t+1} = \alpha D_{t+1} + (1 - \alpha)(L_t + T_t)$$
$$T_{t+1} = \beta(L_{t+1} - L_t) + (1 - \beta)T_t$$

42

Holt's Exponential Smoothing

- Supermarket Eggs data

What is the forecast of week 101 (Use a=4, b=2000)?

What is the forecasting error of week 101?

What is the forecast of week 102 (use $\alpha=0.2$, $\beta=0.2$)?

43

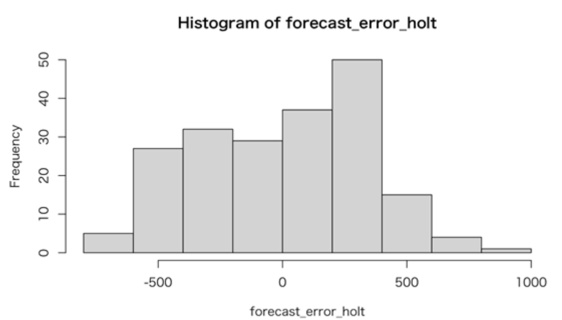
Holt's Exponential Smoothing Exercise I

- What is the forecast demand for week 301 using Holt's exponential smoothing, starting from week 101?
- [challenging] Suppose that the price of a cartoon of eggs is $4, and the cost is $0.8. You order the eggs once a week, and throw away all leftovers, i.e., salvage value of $0. Then, right before week 301, without knowing the actual demand, how many cartoons of eggs you will order, using the Holt's exponential smoothing model?

44

Holt's ES Exercise

- The distribution of the forecast → point forecast + forecasting errors



45

Holt's ES Exercise II

- Compared to the simple ES model, what is the daily value of Holt's exponential smoothing forecasting system with α=0.2 , β=0.2 ?

46

Trend- and Seasonality-Corrected Exponential Smoothing (Winter's Model)

- Appropriate when the systematic component of demand **has a level, trend, and seasonal factor**

Systematic component = (level + trend) x seasonal factor

$$F_{t+1} = (L_t + T_t)S_{t+1} \text{ and } F_{t+l} = (L_t + lT_t)S_{t+l}$$

47

Trend- and Seasonality-Corrected Exponential Smoothing

- After observing demand for period $t + 1$, revise estimates for level, trend, and seasonal factors

$$L_{t+1} = \alpha(D_{t+1}/S_{t+1}) + (1 - \alpha)(L_t + T_t)$$

$$T_{t+1} = \beta(L_{t+1} - L_t) + (1 - \beta)T_t$$

$$S_{t+p+1} = \gamma(D_{t+1}/L_{t+1}) + (1 - \gamma)S_{t+1}$$

α = smoothing constant for level
β = smoothing constant for trend
γ = smoothing constant for seasonal factor

48

Time Series Models

Forecasting Method	**Applicability**
Moving average	No trend or seasonality
Simple exponential smoothing	No trend or seasonality
Holt's model	Trend but no seasonality
Winter's model	Trend and seasonality

49

Measures of Forecast Error

$$MSE_n = \frac{1}{n}\sum_{t=1}^{n} E_t^2$$

$$A_t = \left|E_t\right| \qquad MAD_n = \frac{1}{n}\sum_{t=1}^{n} A_t \qquad \sigma = 1.25MAD$$

$$MAPE_n = \frac{\sum_{t=1}^{n}\left|\frac{E_t}{D_t}\right|100}{n}$$

50