Risk pooling strategies to reduce and hedge uncertainty

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(based on material developed by Prof. Gerard Cachon, The Wharton School)

Risk pooling strategies

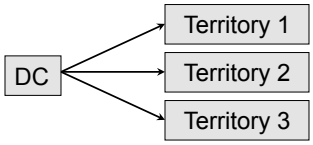
- The objective of a risk pooling strategy is to redesign the supply chain, the production process or the product to either reduce the uncertainty the firm faces or to hedge uncertainty so that the firm is in a better position to mitigate the consequence of uncertainty.
- We will discuss four versions of risking pooling:
  - location pooling
  - product pooling
    - universal design
    - component commonality
  - lead time pooling
    - delayed differentiation (HP case)
    - consolidated distribution
  - capacity pooling

Risk pooling strategies:

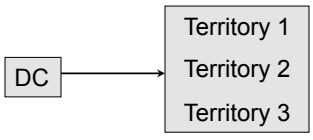
Location pooling

Location pooling at Medtronic

- Current operations:
  - Each sales representative has her own inventory to serve demand in her own territory.
  - Lead time is 1 day from Mounds View DC
  - e.g., 3 territories, 3 stockpiles of inventory



- The location pooling strategy:
  - A single location stores inventory used by several sales reps.
  - Sales reps no longer hold their own inventory, they must pull inventory from the pooled location.
  - Inventory is automatically replenished at the pooled location as depleted by demand.
  - Lead time to pooled location is still 1 day from Mounds View DC.
  - e.g., 3 pooled territories, 1 stockpile of inventory



The impact of location pooling on inventory

- Suppose each territory's expected daily demand is 0.29, the required in-stock probability is 99.9% and the lead time is 1 day with individual territories or pooled territories.

			Expected inventory		Pipeline inventory	
Number of territories pooled	Pooled territory's expected demand per day (a)	S	units (b)	days-of-demand (b/a)	units (c)	days-of-demand (c/a)
1	0.29	4	3.4	11.7	0.29	1.0
2	0.58	6	4.8	8.3	0.58	1.0
3	0.87	7	5.3	6.1	0.87	1.0
4	1.16	8	5.7	4.9	1.16	1.0
5	1.45	9	6.1	4.2	1.45	1.0
6	1.74	10	6.5	3.7	1.74	1.0
7	2.03	12	7.9	3.9	2.03	1.0
8	2.32	13	8.4	3.6	2.32	1.0

- Pooling 8 territories reduces expected inventory from 11.7 days-of-demand down to 3.6.
- But pooling has no impact on pipeline inventory.

Risk pooling strategies:

Product pooling

Product pooling – universal design

- O'Neill sells two Hammer 3/2 wetsuits that are identical except for the logo silk screened on the chest.

Surf Hammer 3/2 logo

Dive Hammer 3/2 logo

- Instead of having two Hammer 3/2 suits, O'Neill could consolidate its product line into a single Hammer 3/2 suit, i.e., a universal product, which we will call the "Universal Hammer".

Product pooling analysis assumptions

- Demand for the Surf Hammer is Normally distributed with mean 3192 and standard deviation 1181.
- Suppose demand for the Dive Hammer has the same distribution as the Surf Hammer and their demands are independent:
  - … then the Universal Hammer's demand has mean 2 x 3192 = 6384 and std deviation = sqrt(2) x 1181 = 1670.
- Price, cost and salvage value for the Universal Hammer are the same as for the other two:
  - Hence, C_o is 110 – 90 = 20, C_u = 180-110 = 70
  - Same critical ratio = 70 /(20 + 70) = 0.7778
  - Same optimal *z* statistic, 0.77

Product pooling analysis results

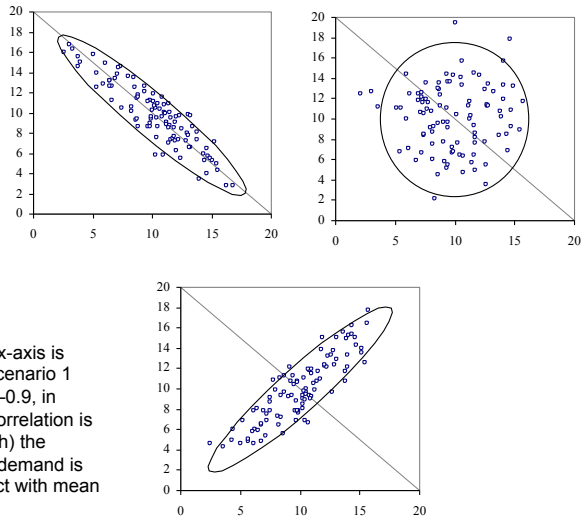
- Performance of the two suits (Surf and Dive)
  - Total order quantity = 2 x 4101 = 8202
  - Total profit = 2 x $191,760 = $383,520
- Universal Hammer
  - Order quantity: $Q = \mu + \sigma \times z = 6384 + 1670 \times 0.77 = 7670$
  - Profit:

$$\begin{aligned} Expected\ profit &= \left(C_u \times Expected\ sales\right) - \left(C_o \times Expected\ left\ over\ inventory\right) \\ &= \left(70 \times 6172.4\right) - \left(20 \times 1497.6\right) \\ &= \$402{,}116 \end{aligned}$$

  - Reduces inventory investment by (8202-7670)/8202 = 6.5%
  - Increase profit by (402116-383520)/383520 = 4.85%
  - The profit increase of 4.85% = 1.45% of revenue

Demand correlation

- Correlation refers to how one random variable's outcome tends to be related to another random variable's outcome.

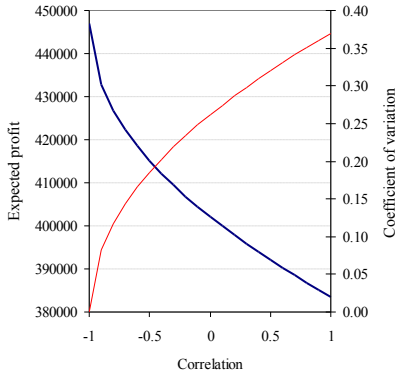


Random demand for two products (x-axis is product 1, y-axis is product 2). In scenario 1 (upper left graph) the correlation is –0.9, in scenario 2 (upper right graph) the correlation is -0 and in scenario 3 (the lower graph) the correlation is 0.90. In all scenarios demand is Normally distributed for each product with mean 10 and standard deviation 3.

Key driver of product pooling

- Product pooling is most effective if the coefficient of variation of the Universal product is lower than the coefficient of variation (COV) of the individual products:
  - COV for Surf and Dive Hammers = 1181/3192 = 0.37
  - COV for Universal Hammer = 1670/6384 = 0.26
- Negative correlation in demand for the individual products is best for reducing COV

$$Coefficient\ of\ variation\ of\ pooled\ demand = \sqrt{\frac{1}{2}(1 + Correlation)} \times \left(\frac{\sigma}{\mu}\right)$$



The correlation between surf and dive demand for the Hammer 3/2 and the expected profit of the universal Hammer wetsuit (decreasing curve) and the coefficient of variation of total demand (increasing curve)

Limitations of product pooling/universal product

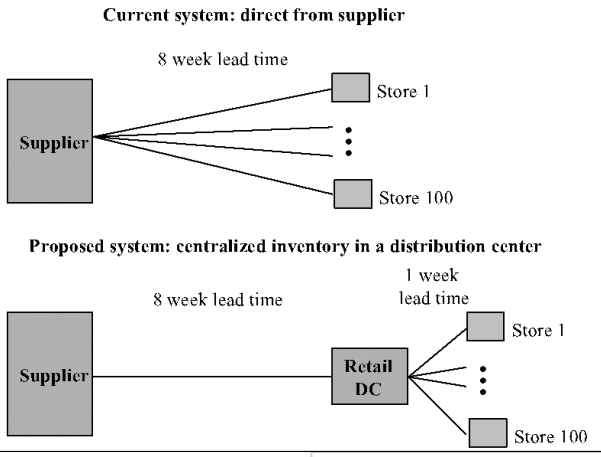
- A universal product may not provide key functionality to consumers with special needs:
  - High end road bikes need to be light, high end mountain bikes need to be durable. It is hard to make a single bike that performs equally well in both settings.
- A universal product may be more expensive to produce because additional functionality may require additional components.
- But a universal product may be less expensive to produce because each component is needed in a larger volume.
- A universal product may eliminate brand/price segmentation opportunities:
  - There may be a need to have different brands (e.g., Lexus vs Toyota) and different prices to cater to different segments.

Risk pooling strategies:

Lead time pooling

Lead time pooling – consolidated distribution

- Consider the following two systems:
  - In each case weekly demand at each store is Poisson with mean 0.5 and the target in-stock probability at each store is 99.5%



DC demand is normally distributed with mean 50 and standard deviation 15

If demands were independent across stores, then DC demand would have a standard deviation of sqrt(50) = 7.07

Consolidated distribution results

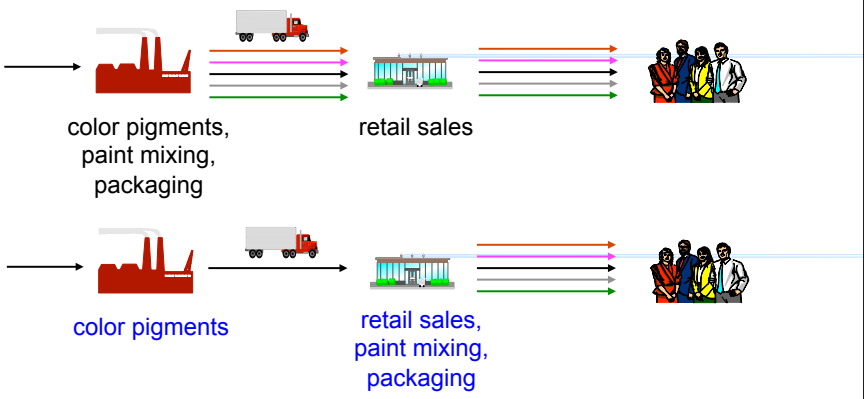
	Direct delivery	Consolidated distribution	Location pooling
Expected total inventory at the stores	650	300	0
Expected inventory at the DC	0	116	116
Pipeline inventory between the DC and the stores	0	50	0
Total	650	466	116

- Consolidated distribution reduces total inventory by 28% and retail inventory by 54%
- It is not as effective as location pooling, but inventory remains at multiple retail locations.
- Other issues:
  - It facilitates purchasing in large quantities to obtain discounts and to gain economies of scale in transportation.
  - But it does increase total distance traveled from supplier to retail stores.

Lead time risk pooling – delayed differentiation

- A Universal Hammer 3/2 increases O'Neill's profit, but does not allow O'Neill to differentiate between the Surf and the Dive markets.
- Delayed differentiation is an alternative to the Universal Hammer:
  - O'Neill stocks "generic" Hammers that have no logo.
  - When demand occurs O'Neill quickly silk screens on the appropriate logo, i.e., the Surf Hammer and the Dive Hammer are still offered.
  - This generates the same profit as the Universal Hammer!
- When does delayed differentiation make sense:
  - Customers demand variety.
  - There is less uncertainty with total demand than demand for individual versions.
  - Variety is created late in the production process.
  - Components needed for variety are inexpensive relative to the generic component.
  - Variety can be added quickly and cheaply.

Delayed differentiation with retail paint



Other examples of delayed differentiation

- Private label soup manufacturer:
  - Problem: many different private labels (Giant, Kroger, A&P, etc)
  - Solution: Hold inventory in cans without labels, add label only when demand is realized.
- Black and Decker:
  - Sell the same drill to different retailers that want different packaging.
  - Place drills in packages only when demand is realized.
- Nokia:
  - Customers want different color phones.
  - Design the product so that color plates can be added quickly and locally.

Risk pooling strategies:

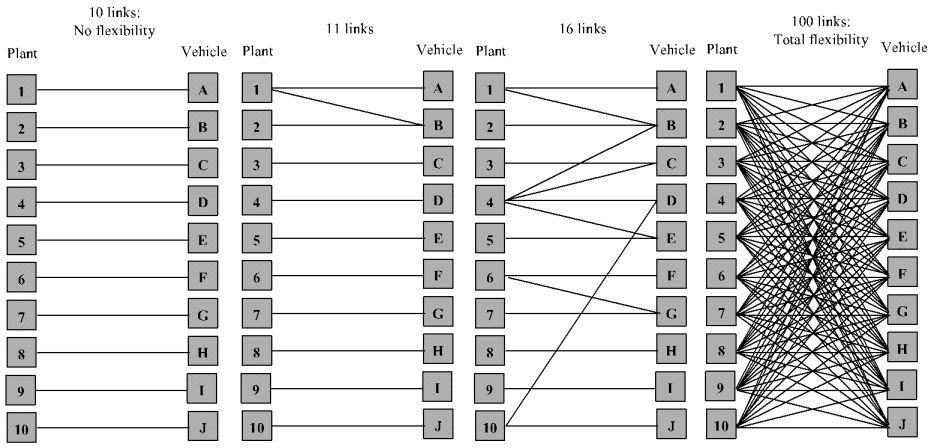
Capacity pooling

Capacity pooling with flexible manufacturing

- Consider the following stylized situation faced by GM …
  - They have 10 production facilities
  - They have 10 vehicles to produce (GMC truck, Chevy Tahoe, Buick Roadmaster, etc).
  - Each plant is capable of producing 100 units.
  - Demand for each product is Normally distributed with mean 100 and standard deviation 40.
  - Each plant can be configured to produce up to 10 products
  - Flexibility is expensive: the cost to construct a plant is increasing in the number of products it can produce.
  - GM must decide which plants can produce which products before demand is realized.
  - After demand is realized, GM can allocate its capacity to satisfy demand.
  - If demand exceeds capacity, sales are lost.

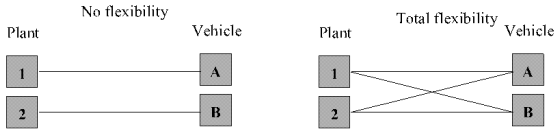
Four possible capacity configurations: no flexibility to total flexibility

- The more links in the configuration, the more flexibility constructed
- In the 16 link configuration plant 4 is flexible enough to produce 4 products but plant 5 has no flexibility (it produces a single product).



How is flexibility used

- Flexibility allows production shifts to high selling products to avoid lost sales.
- Consider a two plant, two product example and two configurations, no flexibility and total flexibility:



- If demand turns out to be 75 for product A, 115 for product B then..

With no flexibility

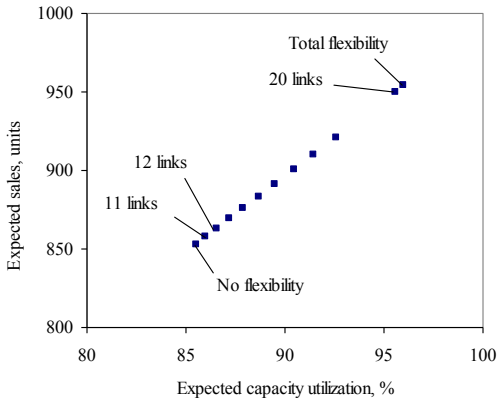
		Production		
Product	Demand	Plant 1	Plant 2	Sales
A	75	75	0	75
B	115	0	100	100
Total Sales		175		
Plant Utilization		88%		

With total flexibility

		Production		
Product	Demand	Plant 1	Plant 2	Sales
A	75	75	0	75
B	115	15	100	115
Total Sales		190		
Plant Utilization		95%		

The value of flexibility

- Adding flexibility increases capacity utilization and expected sales:

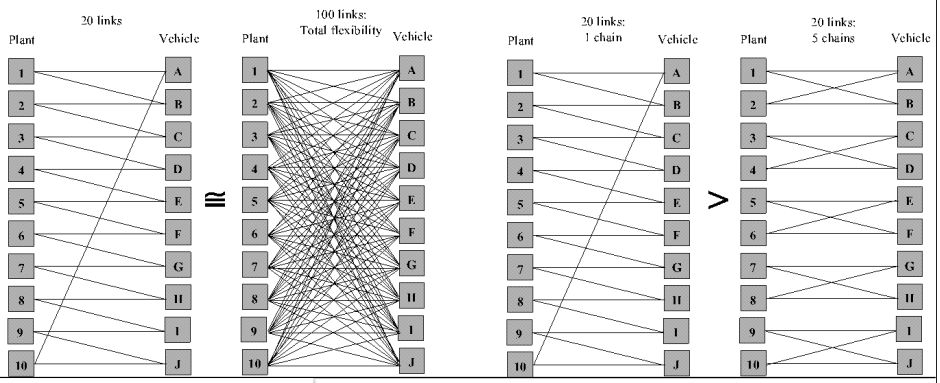


These data are collected via simulation

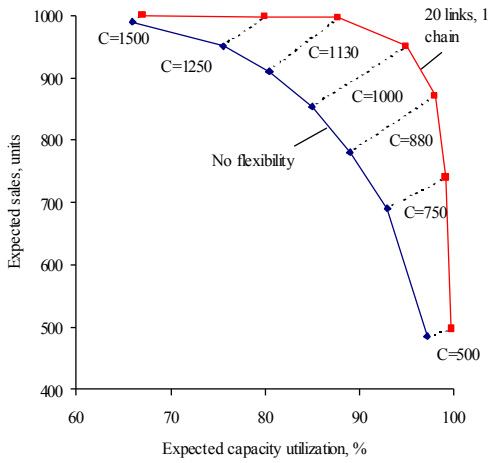
- Note: 20 links can provide nearly the same performance as total flexibility!

Chaining: how to add flexibility

- A chain is a group of plants and products connected via links.
- Flexibility is most effective if it is added to create long chains.
- A configuration with 20 links can produce nearly the results of total flexibility as long as it constructs one large chain:
- Hence, a little bit of flexibility is very useful as long as it is designed correctly



When is flexibility valuable?



C = total capacity of all ten plants

- Observations:
  - Flexibility is most valuable when capacity approximately equals expected demand.
  - Flexibility is least valuable when capacity is very high or very low.
  - A 20 link (1 chain) configuration with 1000 units of capacity produces the same expected sales as 1250 units of capacity with no flexibility.
    - If flexibility is cheap relative to capacity, add flexibility.
    - But if flexibility is expensive relative to capacity, add capacity.

Risk pooling summary

- Risk pooling strategies are most effective when total demand uncertainty is lower than the uncertainty for individual products/locations.
- A little bit of risk pooling goes a long way:
  - With location pooling the biggest bang is from pooling a few locations
  - With capacity pooling a little bit of well designed flexibility is very effective.
- Risk pooling strategies do not help reduce pipeline inventory.
- Risk pooling allows a firm to "have its cake and eat it too"
  - It is possible to lower inventory and increase service simultaneously.