MASSACHUSETTS INSTITUTE OF TECHNOLOGY

MIT Center for Transportation & Logistics

Supply Chain Complexity: Eliminate or Embrace?

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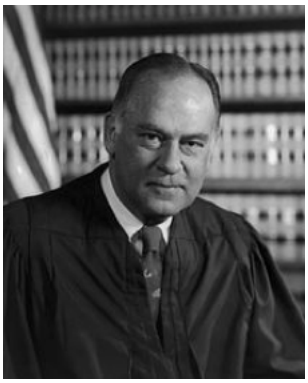
Supply Chain Complexity

- There is a general consensus that . . .
  - supply chains are complex,
  - they are only getting more complex, and
  - complexity adds costs to a supply chain,

Therefore, we should look to mitigate or minimize complexity.

However, some believe that some complexity is good and should be embraced.

What is complexity?



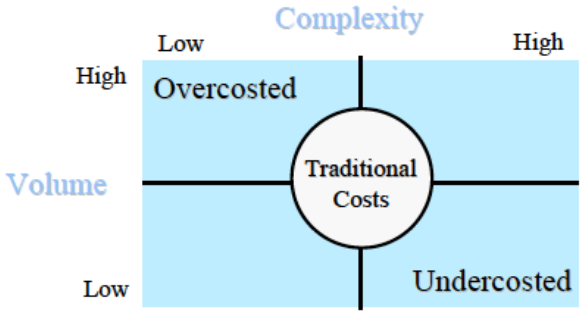
US Supreme Court Justice Potter Stewart
1915 - 1985

"I know it when I see it"
Justice Potter Stewart, in Jacobellis v. Ohio regarding possible obscenity in a movie.

Questions to Be Answered

1. What is complexity?
2. What are the drivers of complexity?
3. How is complexity introduced into a Supply Chain?
4. How can you determine which aspects of complexity to eliminate and which to embrace?
   - How can you eliminate complexity?
   - How can you embrace complexity?

Traditional Systems Distort Product and Customer Costs



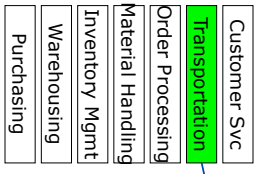
Product Complexity
- Small batch sizes
- Long set-up times
- Unique components
- Special inspection and tests
- Extensive material handling
- Special vendors

Customer Complexity
- Customized products
- Short lead times
- Unpredictable orders
- Extensive technical support
- Extensive post-sales support
- Special tests and requirements

Source: "Introduction to Activity-Based Costing," Robert S. Kaplan, Harvard Business School Publishing, July 5, 2001. (Product Number: 197076)

Supply Chain as a System

- Take an Engineering Systems Perspective
  - What is a variable and what is a constraint?
  - Continuous expansion of decision variables
  - Increases potential for improvement but increases both complexity and coordination requirements



Objective: Deliver at lowest transport cost
Variable:
- Select carrier to tender each load to

Constraints:
- Ship everything each day
- Must deliver within specified windows

Supply Chain as a System

- Take an Engineering Systems Perspective
  - What is a variable and what is a constraint?
  - Continuous expansion of decision variables
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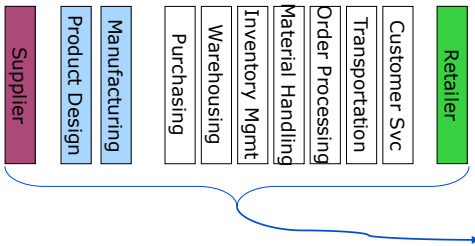

Objective:
- Maximize on-shelf availability

Variables:
- Select carrier to tender each load to
- Select time windows to deliver
- Select when to ship what from where
- Determine where to stock which form of product
- Select contract relationships
- Select who should control replenishment
- Which channel member should perform which function

Constraints:
- Total delivered cost to shelf

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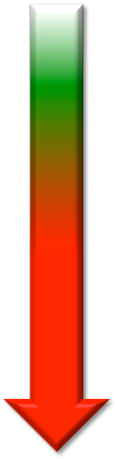
What is complexity? . . . from the literature

- Distinction between complicated and complex.
- Two types of complexity (Singe 1990)
  - Detail Complexity – distinct number of processes or parts within the system
  - Dynamic Complexity – unpredictability of response of the system due to interactions
- A system is complex if it "is made up of a large number of parts that interact in a non-simple way." (Simon 1962)

Source: Bozarth et al, "Impact of Supply Chain Complexity on Manufacturing Plant Performance," JOM 2009.

What are the drivers of SC Complexity?



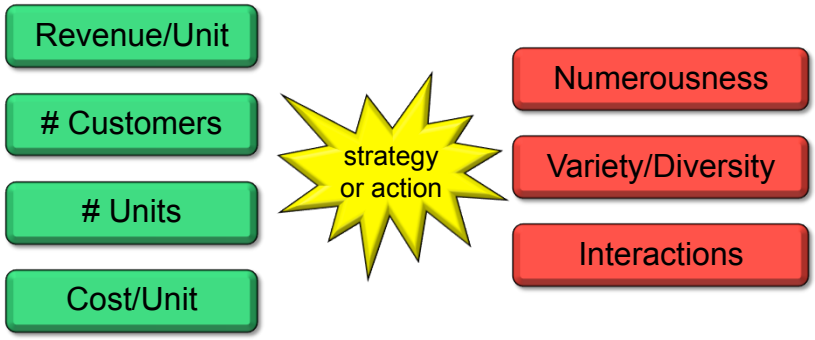
1. Numerousness
2. Variety/Diversity
3. Interconnections/Interactions
4. Opacity of Interactions
5. Dynamic Effects

Source: Mitchell, "Complexity – A Guided Tour" Oxford Press 2009.

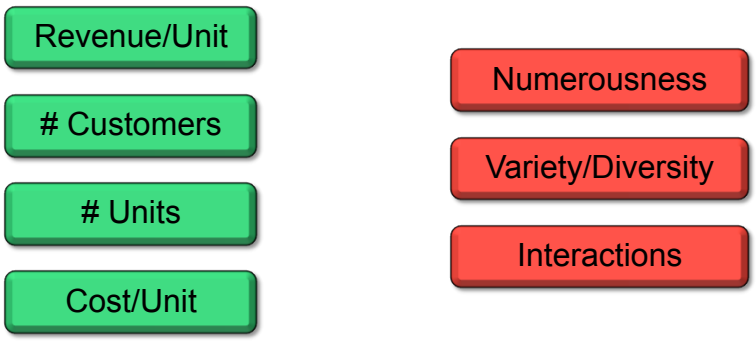
Why do we care?

- Complexity is not introduced for complexity's sake
- Drivers of complexity = Drivers of profitability
- Drivers of profitability
  - Increase revenue per unit
  - Increase the number of customers
  - Increase number of units sold
  - Decrease cost per unit
- Implicit to every strategy or action intended to improve profitability is a hidden cost of complexity

Profitability Drivers = Complexity Drivers



Example: Introduce new packaging format



Example: Launch new product line

- Revenue/Unit
- # Customers
- # Units
- Cost/Unit

- Numerousness
- Variety/Diversity
- Interactions

Example: Open a joint DC for online and traditional retail replenishment

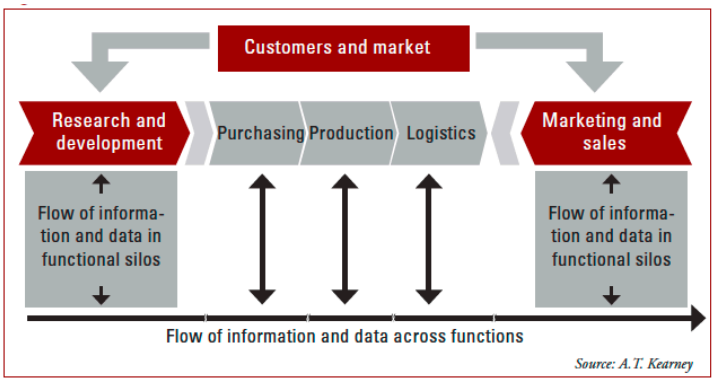
- Revenue/Unit
- # Customers
- # Units
- Cost/Unit

- Numerousness
- Variety/Diversity
- Interactions

Where does complexity enter the supply chain?

Desire for **unique solutions**

Complexity enters at the ends!

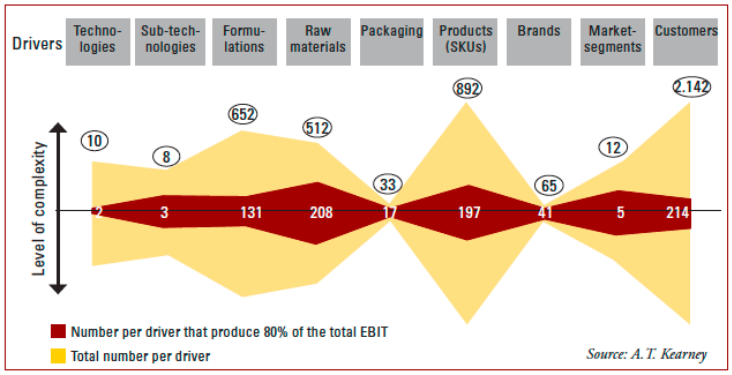


Desire for a **wide and diverse** product portfolio.

Source: Scheiter et al, "How much does complexity really cost?" ATK 2007.

Identifying where complexity lies

Complexity "fingerprint"



Packaging - 17 of 33 configurations account for 80% of EBIT (52%)
Customers - 214 of 2142 (just 10%) customers account for 80% of EBIT

Source: Scheiter et al, "How much does complexity really cost?" ATK 2007.

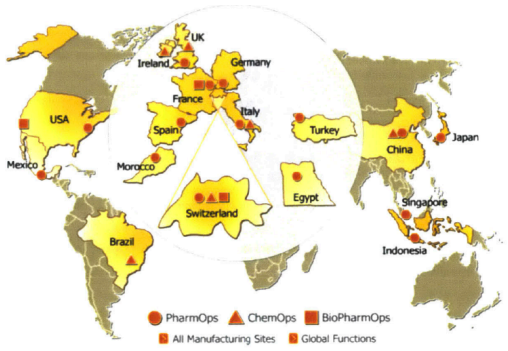
How to determine good vs. bad?

- Value Destroying
  - Does the cost of complexity outweigh the value?
  - Does it introduce greater confusion to the customer?
- Value Creating
  - Is the cost of the complexity less than the increase in value to the customer?
  - Does the added complexity provide potentials for flexibility?
  - Does the added complexity create a competitive advantage?

Complexity Example: Novartis

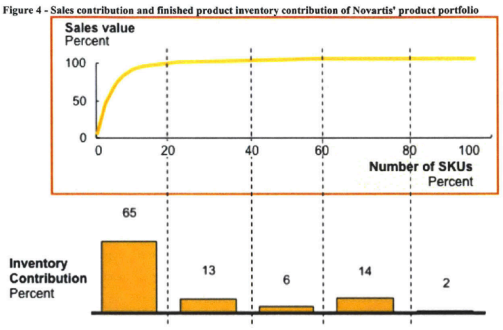
NOVARTIS

- Complexity Reduction Initiative (2010)
  - 14,000 SKUs sold across 140 countries
  - Multiple dosage forms (film-coated tablets, pre-filled syringes, sugar coated pills, etc.)
  - Multiple pack sizes and formats
  - Regulatory requirements – same product produced at two plants creates two SKUs
  - Difficulty in retiring products – some required by regulation others due to mergers

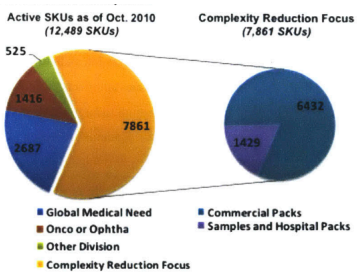


18 Source: Leiter, K., "Assessing and Reducing Product Portfolio Complexity in the Pharmaceutical Industry," MIT Thesis 2011.

Complexity Example: Novartis



Which SKUs to focus on?

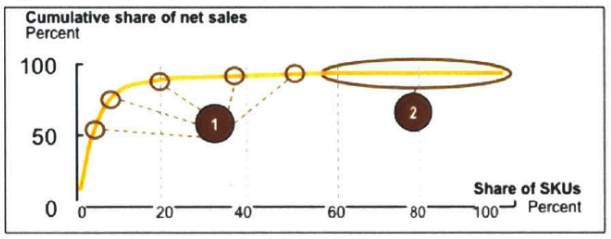


- Didn't reduce entire set of SKUs
- Strategic reasons for limiting set of SKUs
- Consensus between stakeholders for initial analysis and focus

19 Source: Leiter, K., "Assessing and Reducing Product Portfolio Complexity in the Pharmaceutical Industry," MIT Thesis 2011.

Complexity Example: Novartis

- Simultaneous Two Pronged Approach
  - Redundant Product Rationalization
  - Tail-end Pruning



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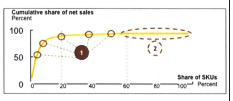
Complexity Example: Novartis

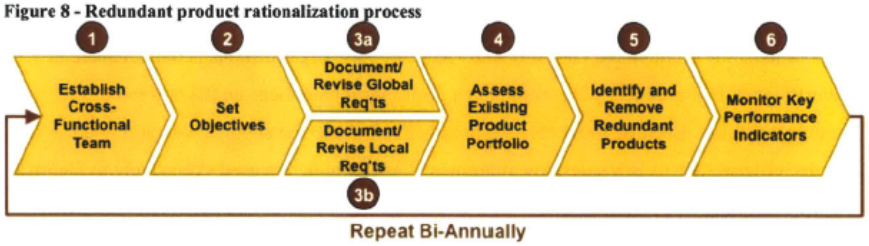
NOVARTIS

Step #1: Redundant Product Rationalization



- Bottoms up approach
- Identify redundant profits by product
- Match true customer requirements and align to products
  - Example: one month vs. two month dosage packs

Figure 8 - Redundant product rationalization process



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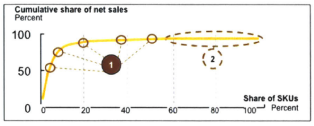
21 Source: Leiter, K., "Assessing and Reducing Product Portfolio Complexity in the Pharmaceutical Industry," MIT Thesis 2011.

Complexity Example: Novartis

NOVARTIS



- Redundant Product Rationalization Results
  - Reduced SKUs by 30% with no sales loss
  - Reduced SKUs lead to better forecasting
  - Very resource intensive initiative
  - Required buy-in by heads of finance & marketing

Brands Reviewed	Active SKUs in Local Portfolio	Rationalization Impact	Remaining SKUs	Driver
Brand A	24	-2	22	Cannot prune SKUs – High packsize variety necessary
Brand B	54	-23	31	Medium pack pruned – 100% sales compensation confirmed
Brand C	62	-25	37	Medium pack pruned – 100% sales compensation confirmed
Brand D	31	-4	27	4 redundant or non-critical SKUs pruned with no sales loss
Brand E	33	-6	27	Hospital packs pruned and pruning of medium pack to be evaluated
Brand F	14	-4	10	Hospital packs and medium packs – replaced by other commercial pack
Brand G	20	-8	12	Hospital packs and medium packs – replaced by other commercial pack

In these 7 brands, the CPO achieved 30% reduction in SKUs (72 SKUs) without sales loss

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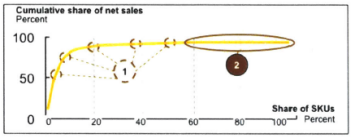
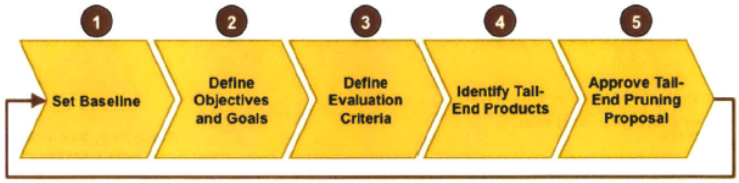
Complexity Example: Novartis



Step #2: Tail-end Pruning

- Top-down approach
- Identify and remove small less profitable products
- Devil is in the details and the tail always regenerates



Repeat Annually

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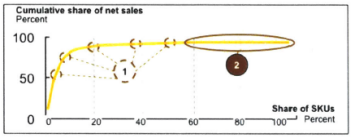
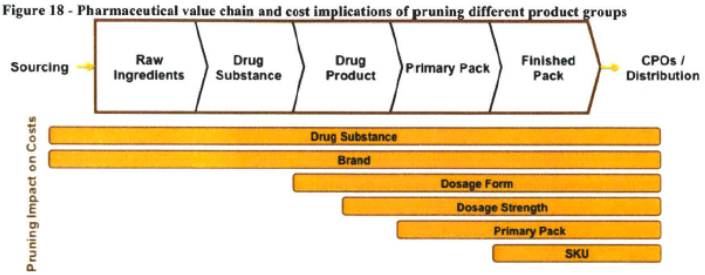
23 Source: Leiter, K., "Assessing and Reducing Product Portfolio Complexity in the Pharmaceutical Industry," MIT Thesis 2011.

Complexity Example: Novartis



- Tail-end Pruning
  - What level of detail makes sense?
  - Measure by SKU by Brand by Drug . . .
  - Two approaches considered:
    - MILP – when high quality data is available
    - Criteria Threshold – when data is imperfect

Figure 18 - Pharmaceutical value chain and cost implications of pruning different product groups



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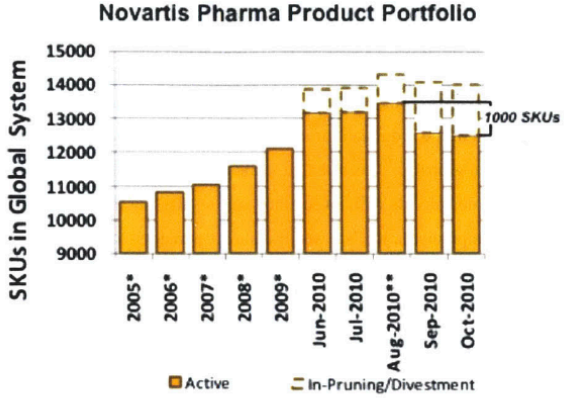
24 Source: Leiter, K., "Assessing and Reducing Product Portfolio Complexity in the Pharmaceutical Industry," MIT Thesis 2011.

Complexity Example: Novartis

- Results of Complexity Reduction Initiative (2010)
  - Approximately 1100 SKUs pruned
  - 43 complete brands were pruned!
  - Inventory savings of $22 M



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25 Source: Leiter, K., "Assessing and Reducing Product Portfolio Complexity in the Pharmaceutical Industry," MIT Thesis 2011.

Complexity Example: Hewlett Packard

- Hewlett-Packard circa 2008
  - More than a billion customers in 170 countries
  - Wide variety of product lines and SKUs
    - > 2,000 Laser Printers
    - >15,000 Server SKUs
    - > 8 million Laptop & Desktop configurations
  - Multiple sales channels with variety of order cycle times
  - Shorter overall product lifecycles
  - New products constantly introduced
    - Marketing decision based on marginal revenue improvement
    - Minimal supply chain input on costs

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26 Source: Ward et al.: HP Transforms Product Portfolio Management with Operations Research Interfaces 40(1), pp. 17–32, ©2010 INFORMS

Complexity Example: Hewlett Packard

- Portfolio Rationalization Project
  - Focus on Personal Systems Group (PSG)
  - Configurable PC products
  - Low per SKU costs – but high underlying costs
  - Orders must ship 100% complete – one component short kills entire order
  - Lead to long and unpredictable Order Cycle Time (OCT)

- Two Simultaneous Initiatives
  1. New Product ROI Screening
     – keeping overly complex products out
  2. Revenue Coverage Optimization
     – for pruning existing products

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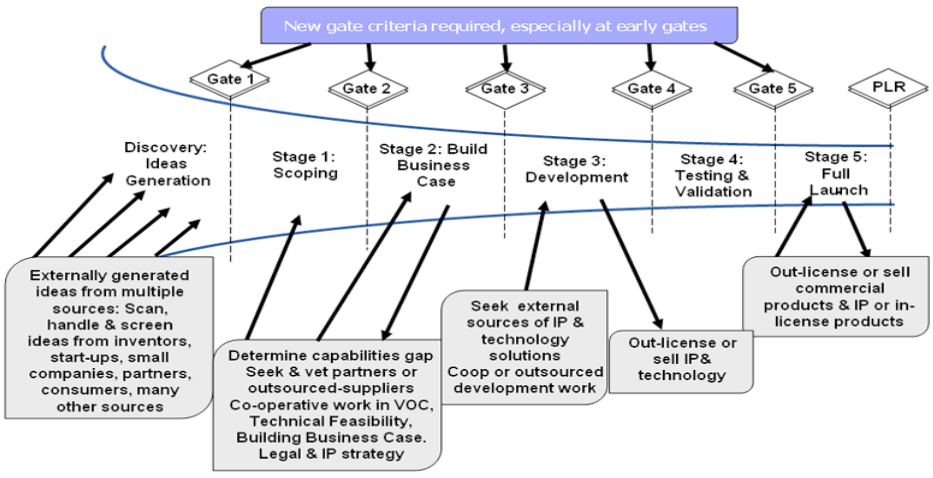
Source: Ward et al.: HP Transforms Product Portfolio Management with Operations Research Interfaces 40(1), pp. 17–32, ©2010 INFORMS

New Product Introduction Process (Stage-Gate)

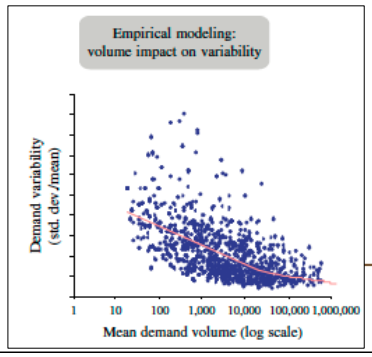
Open Innovation Stage-Gate®: External Interfaces (In-Bound & Out-Bound) at Multiple Points in the Process



Complexity Example: Hewlett Packard

#1: New Product ROI Screening

- ABC approach with volume and variety as distinct drivers
- Used mix of approaches (ABC, regression) for variety drivers
  - More SKUs lead to higher returns
  - Lower volumes leads to higher variability



Cost type	Nature of relationship	Cost categories
Variable complexity costs	Volume-driven	• Material costs: volume discounts • Variability-driven costs: excess costs (financing, storage, depreciation, obsolescence, fire sales) and shortage costs (material price premiums, expediting, lost sales because of shortages)
Fixed complexity costs	Variety-driven	• Resource costs: R&D, testing, product management, etc. • External cash outlays: tooling, costs to contract manufacturer • Indirect impacts of variety: manufacturing switching costs, warranty-program expenses, quality impacts, returns costs

Low Volumes of a SKU drive Costs

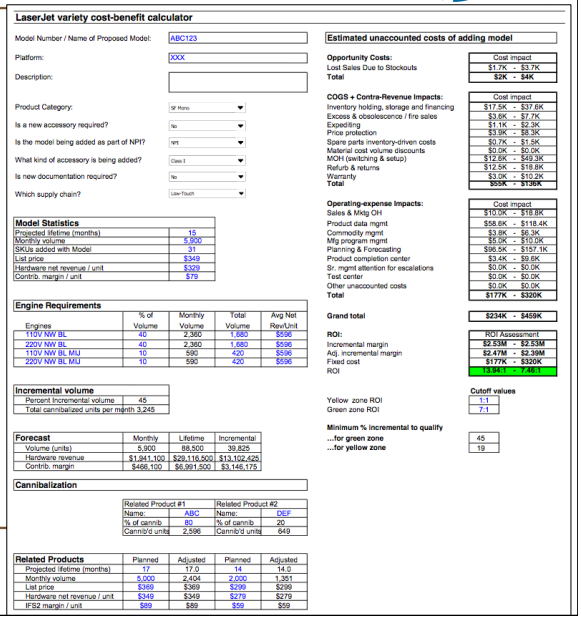
SKUs drive Costs

$$\text{Complexity ROI} = \frac{(\text{Incremental margin} - \text{Variable complexity costs})}{(\text{Fixed complexity costs})}$$

Complexity Example: Hewlett Packard

#1: New Product Screening

- Formed cross functional team (SC, Finance, Mkt) to validate approach
- Reach consensus on *reasonable* rather than *exact* cost model
- Created user friendly tool to assess Complexity ROI for new products



LaserJet variety cost-benefit calculator

Model Number / Name of Proposed Model: ABC123
Platform: XXX
Description:
Product Category: SF Mono
Is a new accessory required? No
Is the model being added as part of NPI? NPI
What kind of accessory is being added? Class I
Is new documentation required? No
Which supply chain? Low-Touch

Model Statistics	
Projected lifetime (months)	15
Monthly volume	5,900
SKUs added with Model	31
List price	$349
Hardware net revenue / unit	$329
Contrib. margin / unit	$79

Engine Requirements	% of Volume	Monthly Volume	Total Volume	Avg Net Rev/Unit
110V NW BL	40	2,360	1,680	$596
220V NW BL	40	2,360	1,680	$596
110V NW BL MU	10	590	420	$596
220V NW BL MU	10	590	420	$596

Incremental volume	
Percent Incremental volume	45
Total cannibalized units per month	3,245

Forecast	Monthly	Lifetime	Incremental
Volume (units)	5,900	88,500	39,825
Hardware revenue	$1,941,100	$29,116,500	$13,102,425
Contrib. margin	$466,100	$6,991,500	$3,146,175

Cannibalization

Related Product #1		Related Product #2	
Name:	ABC	Name:	DEF
% of cannib.	80	% of cannib.	20
Cannib'd units	2,596	Cannib'd units	649

Related Products	Planned	Adjusted	Planned	Adjusted
Projected lifetime (months)	17	17.0	14	14.0
Monthly volume	5,000	2,404	2,000	1,351
List price	$369	$369	$299	$299
Hardware net revenue / unit	$349	$349	$279	$279
IFS2 margin / unit	$89	$89	$59	$59

Estimated unaccounted costs of adding model

Opportunity Costs:	Cost impact
Lost Sales Due to Stockouts	$1.7K - $3.7K
Total	$2K - $4K

COGS + Contra-Revenue Impacts:	Cost impact
Inventory holding, storage and financing	$17.5K - $37.6K
Excess & obsolescence / fire sales	$3.6K - $7.7K
Expediting	$1.1K - $2.3K
Price protection	$3.9K - $8.3K
Spare parts inventory-driven costs	$0.7K - $1.5K
Material cost volume discounts	$0.0K - $0.0K
MOH (switching & setup)	$12.6K - $49.3K
Refurb & returns	$12.5K - $18.8K
Warranty	$3.0K - $10.2K
Total	$55K - $136K

Operating-expense Impacts:	Cost impact
Sales & Mktg OH	$10.0K - $18.8K
Product data mgmt	$58.6K - $118.4K
Commodity mgmt	$3.9K - $6.3K
Mfg program mgmt	$5.0K - $10.0K
Planning & Forecasting	$96.5K - $157.1K
Product completion center	$3.4K - $9.6K
Sr. mgmt attention for escalations	$0.0K - $0.0K
Test center	$0.0K - $0.0K
Other unaccounted costs	$0.0K $0.0K
Total	$177K - $320K

Grand total	$234K - $459K

ROI:	ROI Assessment
Incremental margin	$2.53M - $2.53M
Adj. incremental margin	$2.47M - $2.39M
Fixed cost	$177K - $320K
ROI	13.94:1 - 7.46:1

Cutoff values	
Yellow zone ROI	1:1
Green zone ROI	7:1

Minimum % incremental to qualify	
...for green zone	45
...for yellow zone	19

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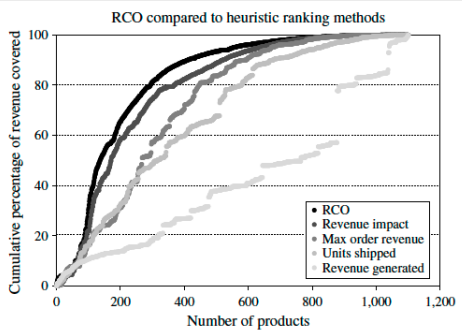
Complexity Example: Hewlett Packard

#2: Revenue Coverage Optimization

- Pruning existing products
- Maximizing value of active portfolio
- Measuring revenue generation by item misses interactions and interdependencies
- RCO answers the question: If I could only have 100 products, which should I choose?
- New metrics:
  - Order Coverage – percent of previous order that could be filled with existing portfolio
  - Revenue Coverage – revenue (margin) of covered orders as a percent of the total revenue



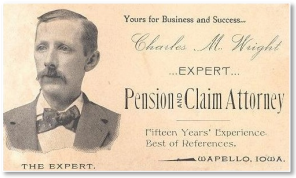
Complexity Example: Hewlett Packard

- Portfolio Rationalization Project Results
  - Over $500 M saved since 2005
  - Product adoption rate improved from 18% to 85%
  - Shift from revenue focused to margin focused management
  - LaserJet SKU count reduced by 40% in 3 years (2006-9)
  - RCO eliminated 3,300 of 11,00 SKUs from HPs Business Critical Systems division
  - Soft benefits
    - Higher customer satisfaction
    - Less confusion for sales and customers
    - Higher forecasting accuracy
    - Better organizational efficiency – forcing Green, Blue & Red to talk!

Source: Ward et al.: HP Transforms Product Portfolio Management with Operations Research Interfaces 40(1), pp. 17–32, ©2010 INFORMS

What about embracing complexity?

- What industry has:
  - Very small batch sizes
  - Long set up times with very short desired lead times
  - Highly customized products (no two are alike)
  - Unpredictable order frequency
  - Many many very small customers

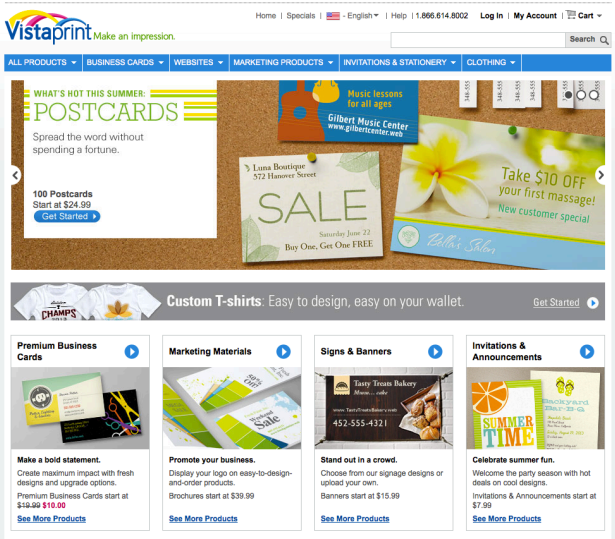


Printing Business Cards

- Traditional Process
  - Relatively high design costs & time
  - High switch over and set up costs between runs
  - Individual card runs – requires high minimum orders
  - Rough costs are about $10-$20 per MSI
    - Business cards are 2" x 3.5" so 500 cards ≈ 3.5 MSI =$35
- Vistaprint
  - Founded in 1995 – profitable in 2001 – IPO 2005
  - Printing business cards and other marketing for micro-businesses

Embracing Complexity Example

Online Design & Ordering

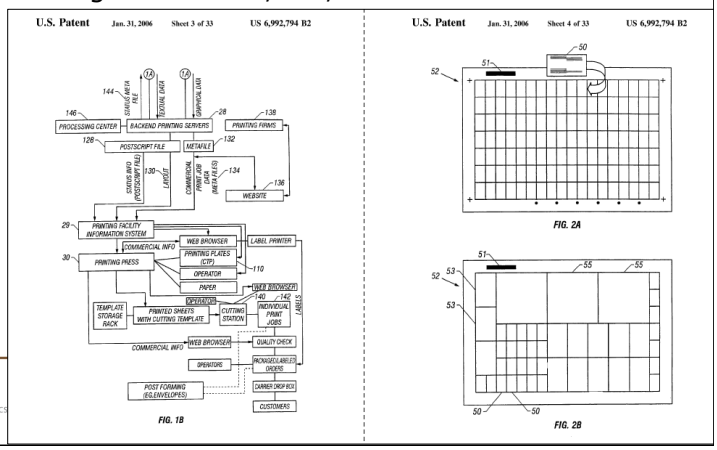


Embracing Complexity Example

- Integrated Production Processes
  - Software tied directly from ordering & design to production
  - Gang Run Printing - Batching together different print jobs into a single print run on a single sheet.
  - Automated sorting, aggregating, and organizing of jobs

Embracing Complexity Example

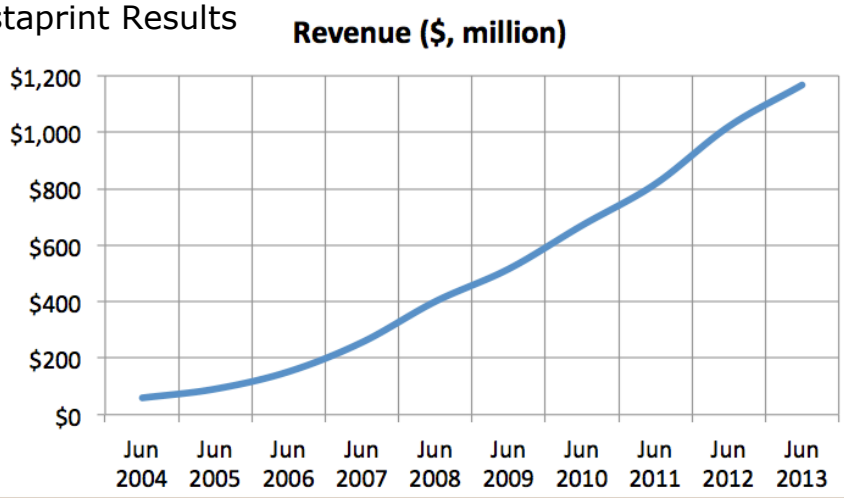
- A "minefield of patents"
- Initial patents filed in France in 2000
- 28 issued in US as of 2013
- Example; VistaBridge - Patent 6,992,794



MIT Center for Transportation & Logistics

Embracing Complexity

Vistaprint Results



Questions to Be Answered

1. What is complexity?
2. What are the drivers of complexity?
3. How is complexity introduced into a Supply Chain?
4. How can you determine which aspects of complexity to eliminate and which to embrace?
   - How can you eliminate complexity?
   - How can you embrace complexity?