Supply Chain Management: Process Integration to Improve Performance

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Outline

- ***Background: supply chain management, performance***
- Definitions: multiple schedule releases, rolling schedules, schedule stability
- Schedule in-stability problem & integrated production planning
- Supply chain design: experiment and results

What is a Supply Chain?

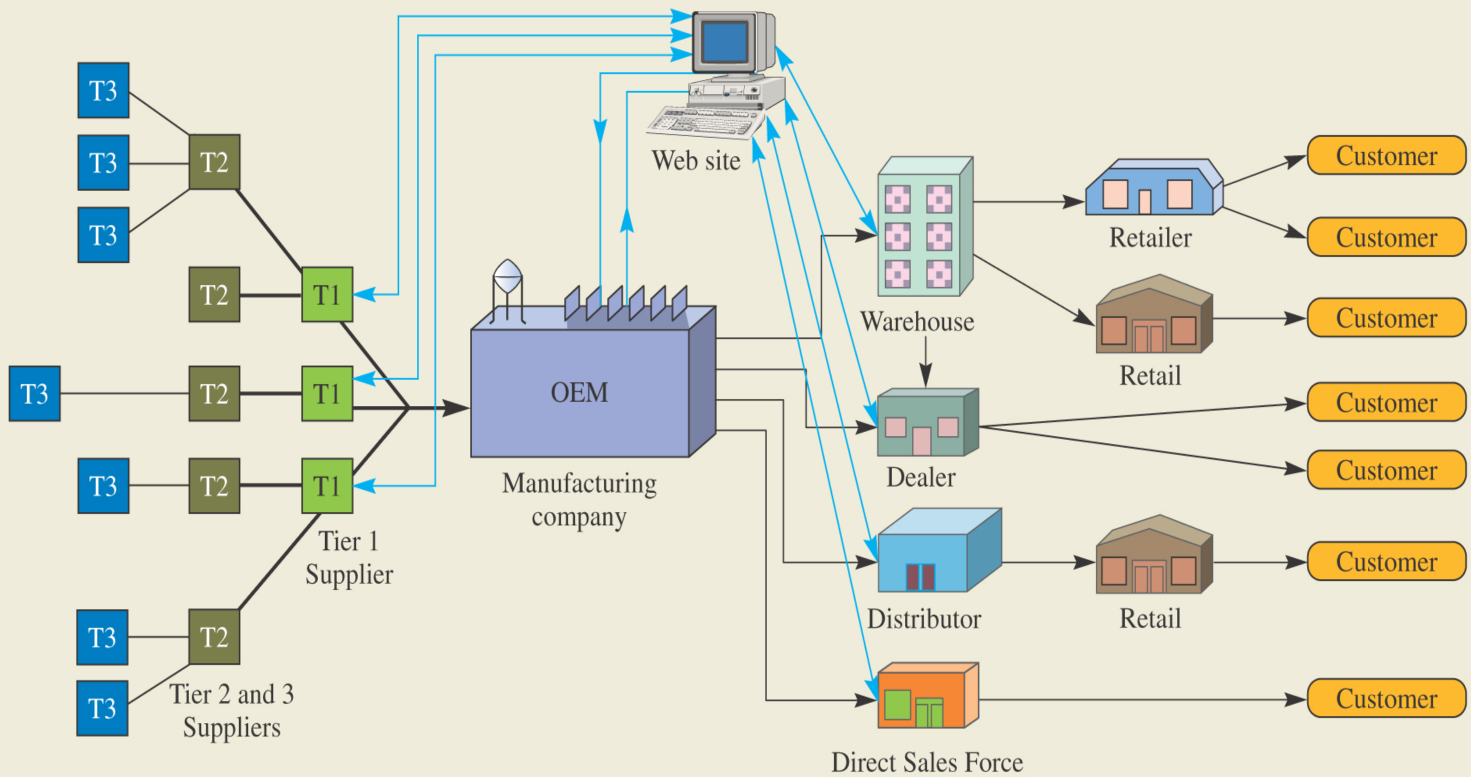
A supply chain consists of the flow and transformation of products and services from:

- Raw materials manufacturers
- Component and intermediate manufacturers
- Final product manufacturers
- Wholesalers and distributors and
- Retailers

Production facilities connected by transportation and storage activities

Integrated through information, planning, and integration activities

Supply Chain of an Original Equipment Manufacturer



As this schematic suggests, a value chain is not a simple linear series of connections. It typically involves a complex series of business interactions and channel configurations. The Web is a key technology enabling efficient communication throughout the chain.

Source: Chase, Aquilano and Jacobs, 2006, Operations Management for Competitive Advantage, McGraw Hill.

Supply Chain Management: *Definition*

- Systems approach to managing the entire flow of information, materials, and services from raw-material suppliers through factories and warehouses to the end customer
- Managing supply chain flows and assets
- Objectives
  - Integrate "entire" process of satisfying the customer's needs
  - To maximize supply chain profitability

Supply Chain Management: Initiatives

- Risk pooling
- Replacing inventory with information
- E-Procurement
- Strategic partnering
- Integrated decision making schemes
- Dynamic Pricing
- Postponement
- Direct-to-Consumer
- International opportunities

Supply Chain Operations Reference Model (SCOR)

Level 1 Metrics	Performance Attributes				
	Customer Facing			Internal	
	Reliability	Responsiveness	Flexibility	Cost	Assets
Perfect Order Fulfillment	✓				
Order Fulfillment Cycle Time		✓			
Upside Supply Chain Flexibility			✓		
Upside Supply Chain Adaptability			✓		
Downside Supply Chain Adaptability			✓		
Supply Chain Management Cost				✓	
Cost of Goods Sold				✓	
Cash-to-Cash Cycle Time					✓
Return on Supply Chain Fixed Assets					✓

[1] Supply Chain Council, 2006, Supply Chain Operations Reference Model, version 7.0

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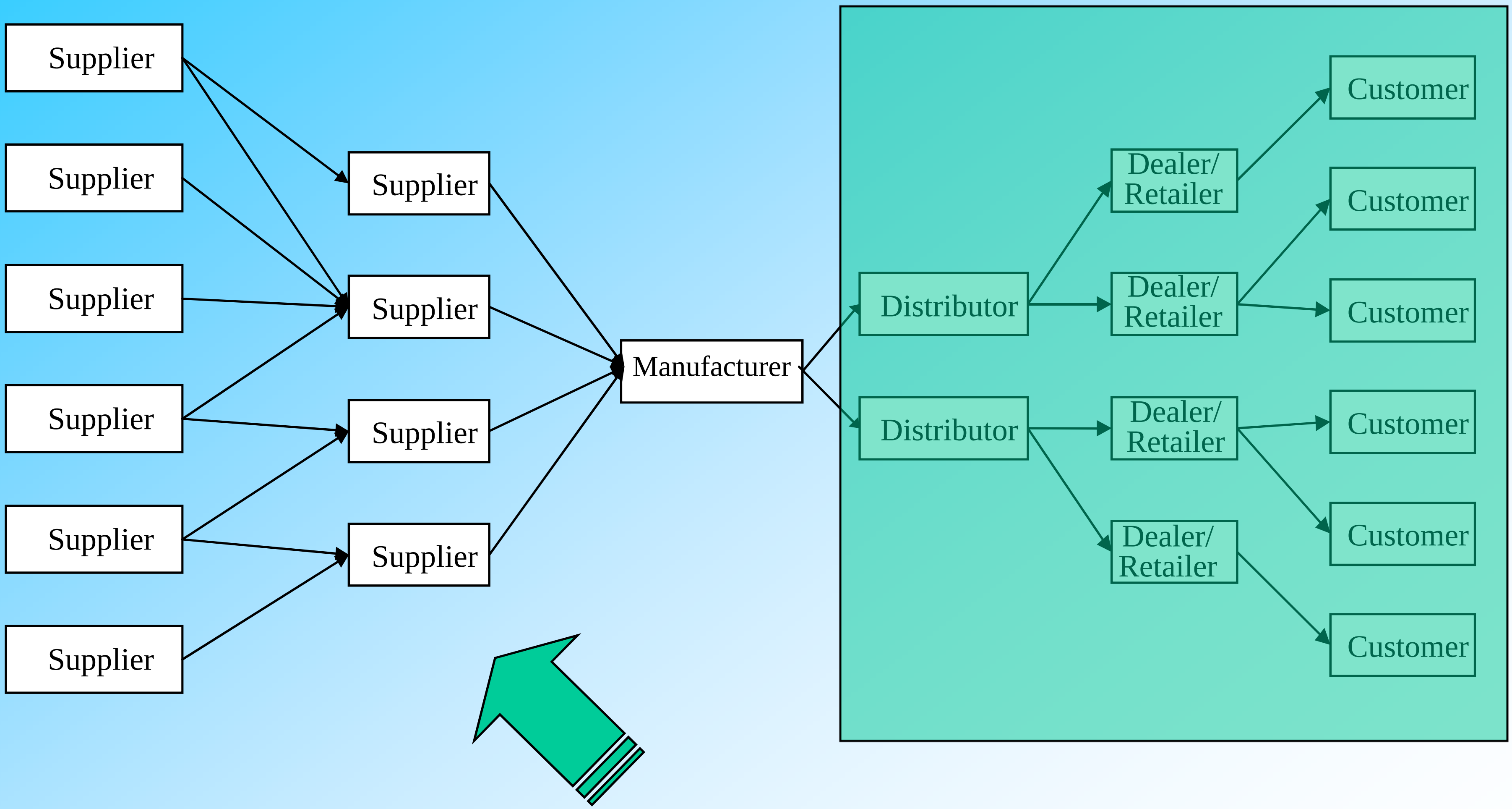
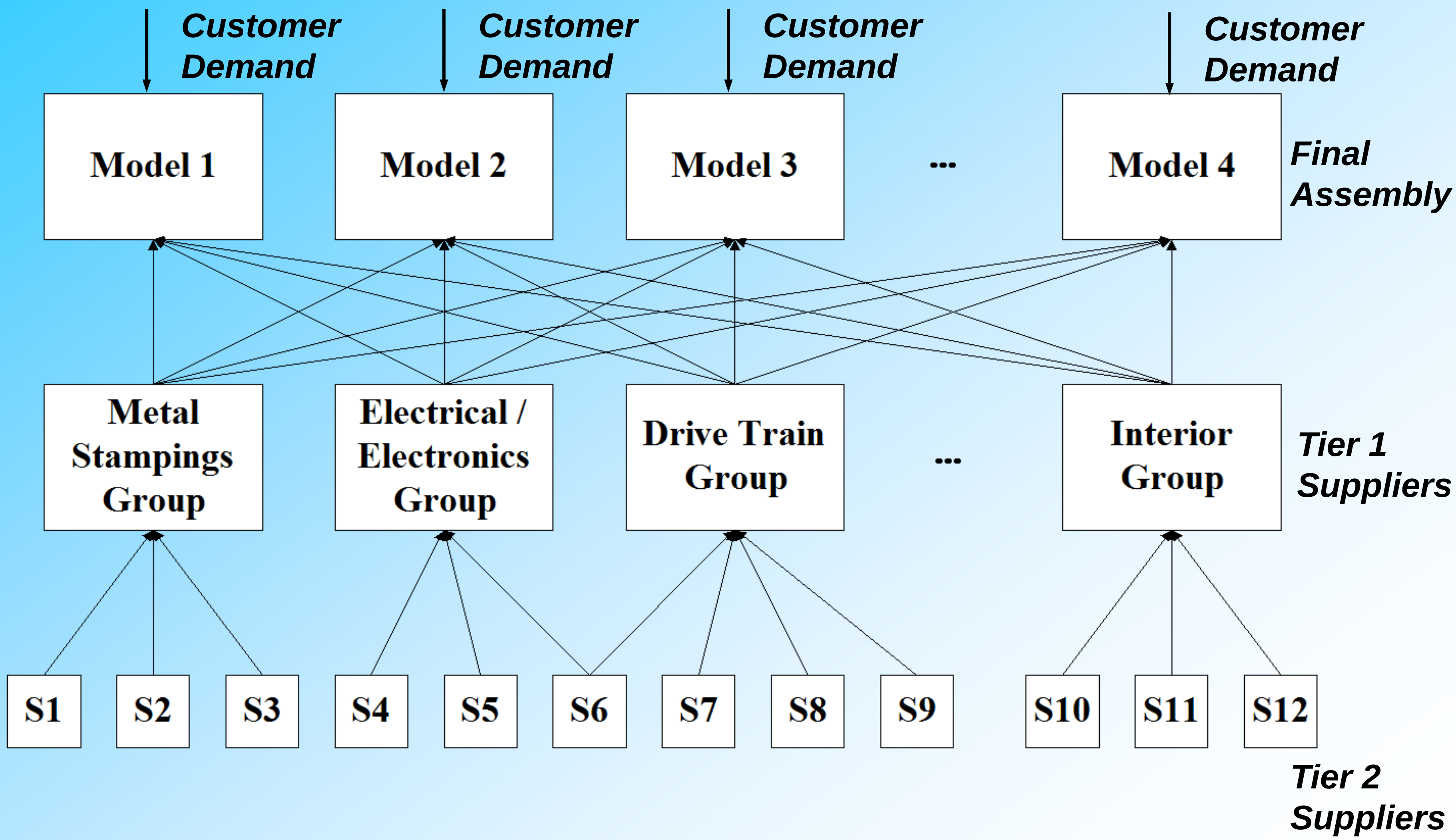
Requirements Planning in the Supply Chain

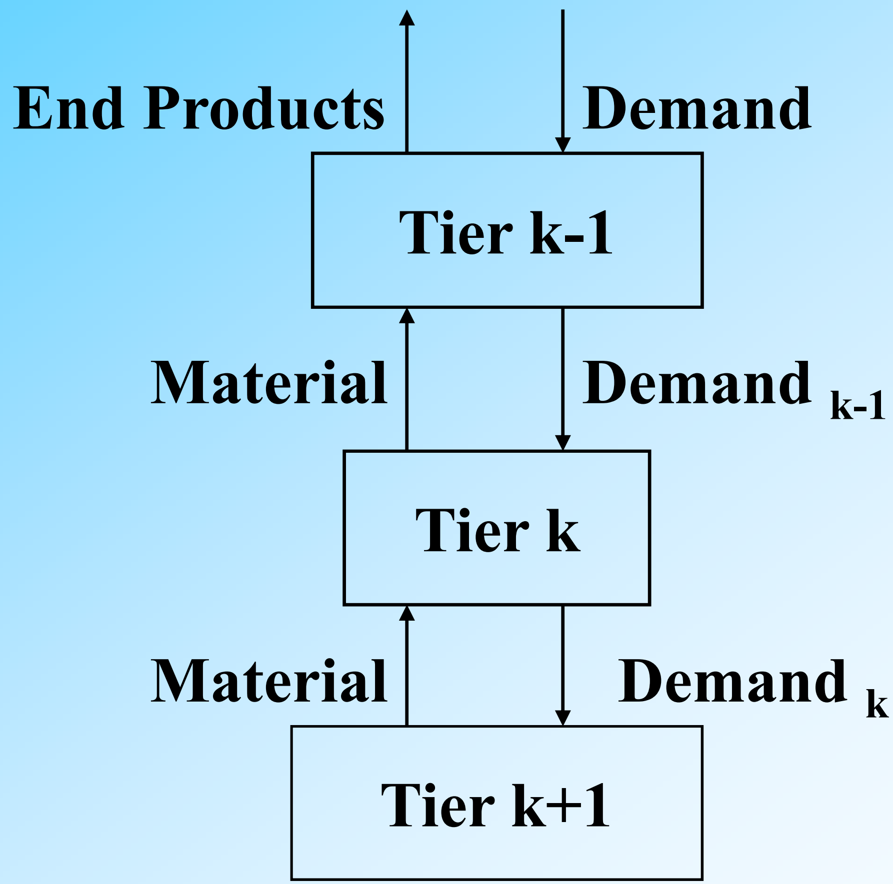


Production Segments of Supply Chain

Supply Chain Example



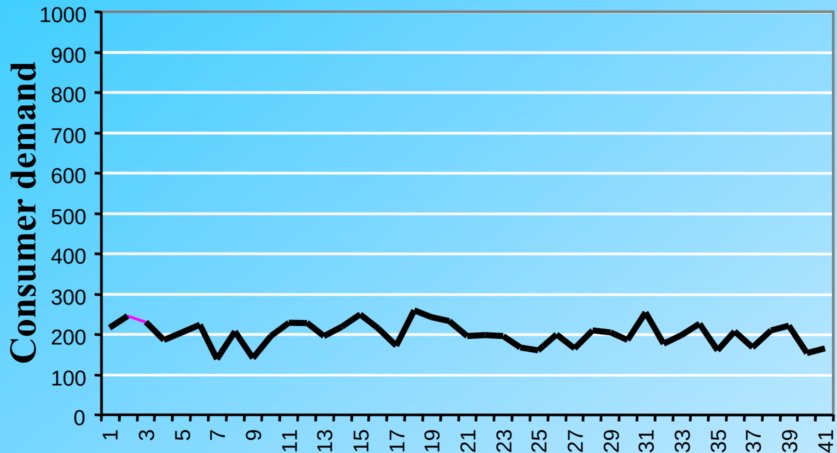
Demand Propagation in a Manufacturing Supply Chain



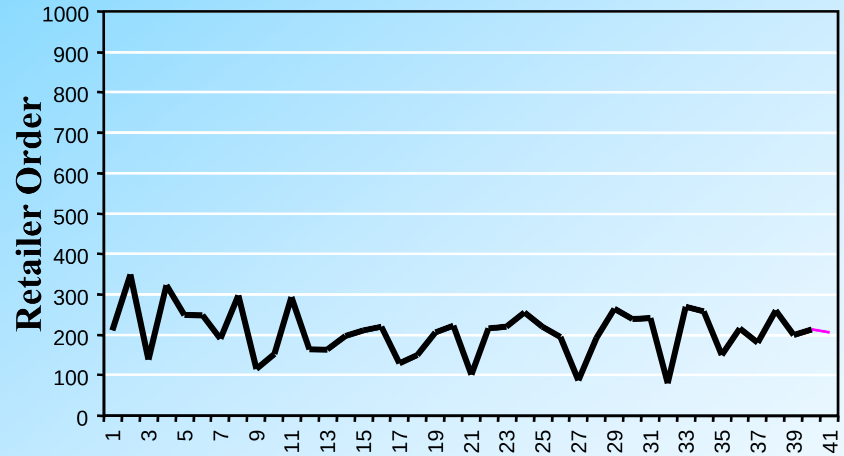
The Bullwhip Effect

Increase in variation as demand translates through a supply chain

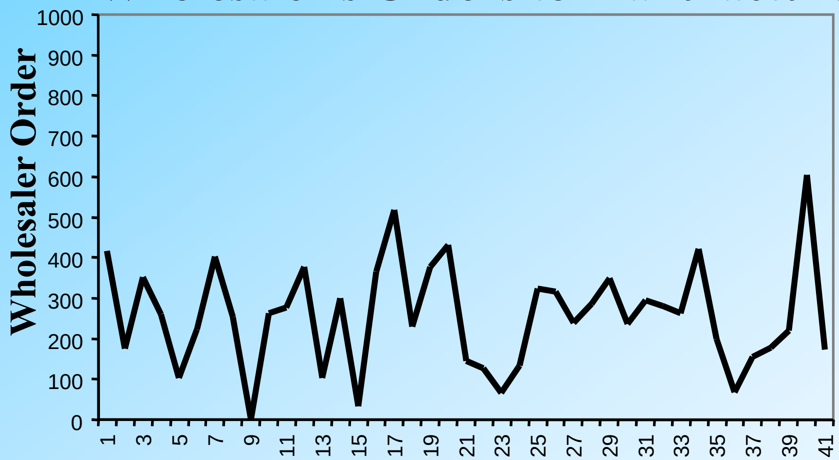
Consumer Sales at Retailer



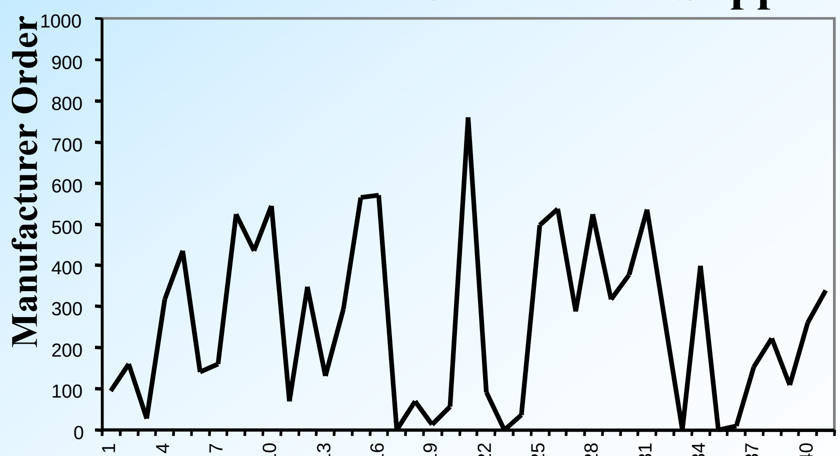
Retailer's Orders to Wholesaler



Wholesaler's Orders to Manufacturer



Manufacturer's Orders with Supplier



Source: Wisner, Tan & Leong 2008, Principles of SCM, Southwestern CENGAGE

Schedule Releases vs. Production Week

	Production Week								
Release Week	**6-May**	**13-May**	**20-May**	**27-May**	**3-Jun**	**10-Jun**	**17-Jun**	**24-Jun**	**...**
6-May	5760	4800	8160	6240	6240	6240	5760	4800	...
13-May		4800	8160	6240	6240	6240	5760	4800	...
20-May			8160	6240	6240	6240	5760	4800	...
27-May				6240	4800	5720	4320	4320	...
3-Jun					4800	5720	4320	4320	...
10-Jun						6240	7200	5760	...
17-Jun							8640	5760	...
24-Jun								5760	...
...									

Level Schedules?

Stable Schedules?

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Problem: Multiple Schedule Releases

- Common approach recommends freezing Master Production Schedule (MPS)
  - Improves cost performance but may be detrimental to customer needs
  - Studies show more than 50% planning horizon needs to be frozen to impact stability (Sridharan, *et al*. 1988)
- Not all changes are “noise” - many valid demand events occur in normal production environment
  - Changes to overall plans and product mix, forecast updates, production losses / gains, inventory adjustments (Inman and Gonzalez, 1999)
- Find strategies for managing schedule releases to improve supply chain performance
  - Structural conditions: capacity utilization, component commonality, batching of customer orders

SCM: Initiatives

- Risk pooling
- Replacing inventory with information
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- Integrated decision making schemes
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- Postponement
- Direct-to-Consumer
- International opportunities

A Framework for Integrating Decisions

Decision Type / Dec. Makers	Trnsp. Chce.	Prdctn. Plnng.	Prchs Qnty.	Lot Size	Spplr. Slctn.	Prdct. Dvlpmnt.	Rtrns.	Dstntn./ Cstmr.					
Factory	A1	A2	A3	A4	A5	A6	A7	A8					
Supplier	B1	B2	B3	B4	B5	B6	B7	B8					
Carrier	C1	C2	C3	C4	C5	C6	C7	C8					
Third Party	D1	D2	D3	D4	D5	D6	D7	D8					

Source: Meixell & Norbis, 2009, "An Integrated Transportation Choice Modeling Framework," *Northeast Decision Science Institute (NEDSI 2009) Conference Proceedings*., Uncasville, CT.

A Framework for Integrating Decisions

Criteria / Decisions Type & Decision Makers	Cost (α)	Quality (β)	Convenience (γ)	Time (δ)	Flexibility (ε)
A1	A1α	A1β	A1γ	A1δ	A1ε
:					
:					
A8	A8α	A8β	A8γ	A8δ	A8ε

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Supplier	**B1**	**B2**	**B3**	**B4**	**B5**	**B6**	**B7**	**B8**					
Carrier	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**					
Third Party	**D1**	**D2**	**D3**	**D4**	**D5**	**D6**	**D7**	**D8**					

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Integrated Production Planning: *Definition*

- An approach to integrated supply and demand planning, typically with web-based visibility tools, across multiple enterprises in supply chain
  - Members of the supply chain established as trading partners with specific planning roles
  - May include a single forecast of demand throughout the chain
  - Supply constraints are either resolved or recognized in operational plan
- Collaboration via ERP-enabled APS provides for cross-tier production planning
- On the integrated framework, problem A2B2α

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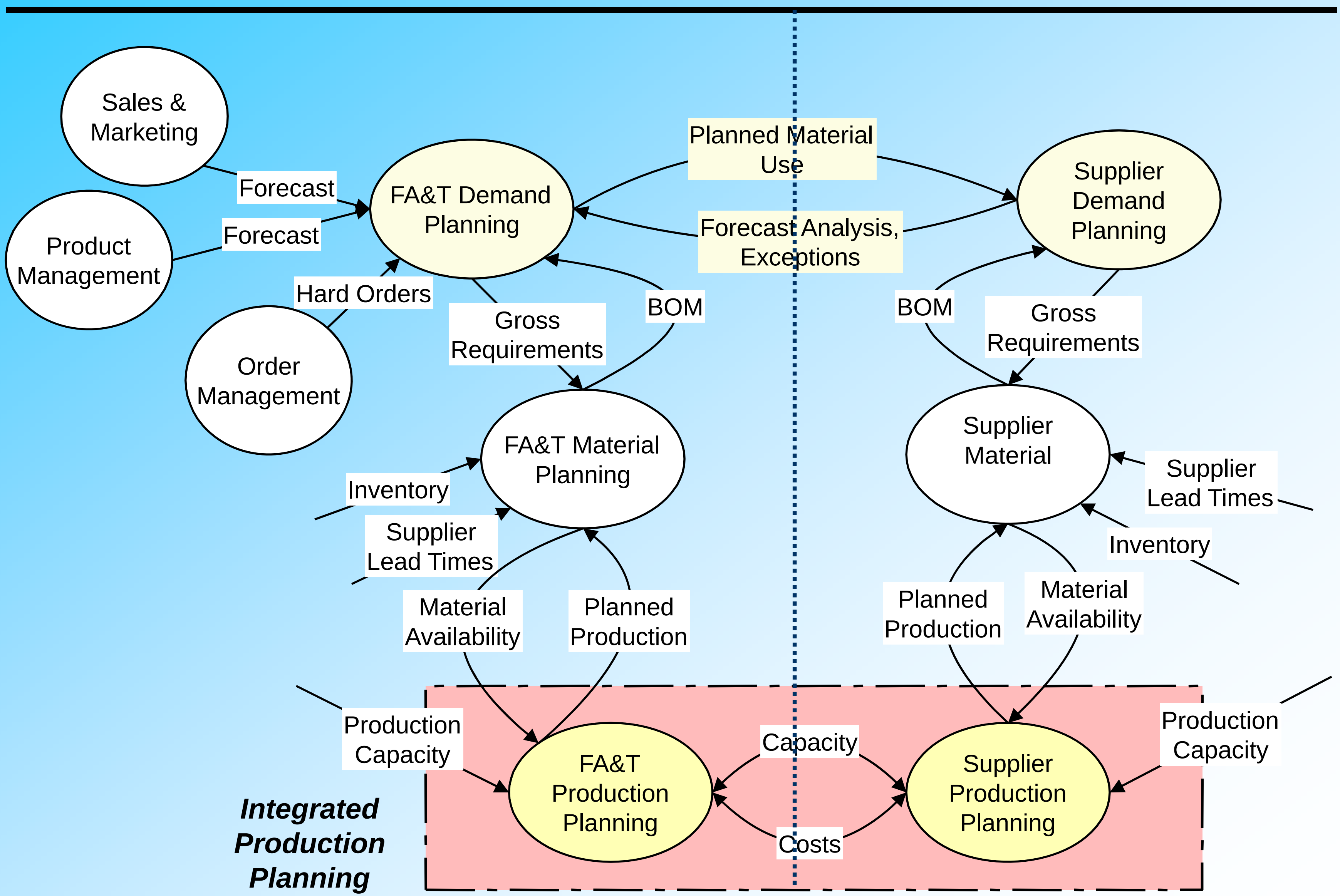
Integrated Production Planning



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- ***Supply chain design: experiment and results***

Research Questions

- What factors influence stability in the supply chain, and how do they interact?
  - Which factors have the greatest influence?
  - At what combination of levels is schedule stability improved?
- What managerial insights can be gained to increase stability of supplier schedules and thereby improve SC performance?

Source: Meixell, M. J. (2005). “The Impact of Capacity, Commonality, and Batching on Schedule Stability: An Exploratory Study,” *International Journal of Production Economics* 95:1, pp 95-107.

Measuring Schedule Stability

$$ST_t = CV(X_t^m)$$

- Coefficient of variation measure
- X_t^m is the schedule quantity for period *t* in release *m*
- Measured across multiple releases for the same production week
- Current production week only

Source: Meixell, M. J. (2005). “The Impact of Capacity, Commonality, and Batching on Schedule Stability: An Exploratory Study,” *International Journal of Production Economics* 95:1, pp 95-107.

Measuring Schedule Stability

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24-Jun								5760	...
...									

$$X^{m}_{t=0624}=(4800, 4800, 4800, 4320, 4320, 5760, 5760, 5760)$$

$$ST_{t=0624}=0.12$$

Source: Meixell, M. J. (2005). “The Impact of Capacity, Commonality, and Batching on Schedule Stability: An Exploratory Study,” *International Journal of Production Economics* 95:1, pp 95-107.

Study Design

- Use optimization model to describe order flow in supply chain
  - Multi-tier capacitated lot sizing model
  - Lagrangian-based heuristic procedure using AMPL/CPLEX
  - Heuristic solution computed, simulating supply chain decisions
- Execute computational experiments
  - Execute selected problem instances, log solutions, compute stability results
  - Perform ANOVA to identify the relationship between factors and schedule stability
- Identify basic characteristics of schedule stability in a supply chain

Source: Meixell, M. J. (2005). "The Impact of Capacity, Commonality, and Batching on Schedule Stability: An Exploratory Study," *International Journal of Production Economics* 95:1, pp 95-107.

Production Model

$$v = \min \sum_{i=1}^{N} \sum_{t=1}^{T} (h_i y_{it} + cs_i \delta_{it})$$

subject to:

$$y_{i,t-1} + f_i x_{i,t-L_i} - y_{it} - \sum_{j=1}^{N} a_{ij} x_{jt} = r_{it} \qquad , \forall i,t$$

$$\sum_{i \in I_k} (b_{ik} x_{it} + s_{ik} \delta_{it}) \leq CAP_{kt} \qquad , \forall k,t$$

$$x_{it} - q_{it} \delta_{it} \leq 0 \qquad , \forall i,t$$

$$\delta_{it} = 0,1, \quad x_{it} \geq 0 , \quad y_{it} \geq 0 \qquad , \forall i,t$$

- Multi-item, multi-period, lot-sizing model
- Allows choice of objective functions
- Descriptive/ prescriptive
- Set of identical and repeating individual item decisions
- Captures complex supply structure

Source: Meixell, M. J. (2005). “The Impact of Capacity, Commonality, and Batching on Schedule Stability: An Exploratory Study,” *International Journal of Production Economics* 95:1, pp 95-107.

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  - Heuristic solution computed, simulating supply chain decisions
- Execute computational experiments
  - Execute selected problem instances – setup cost, capacity utilization, product structure
  - Log solutions, compute stability results
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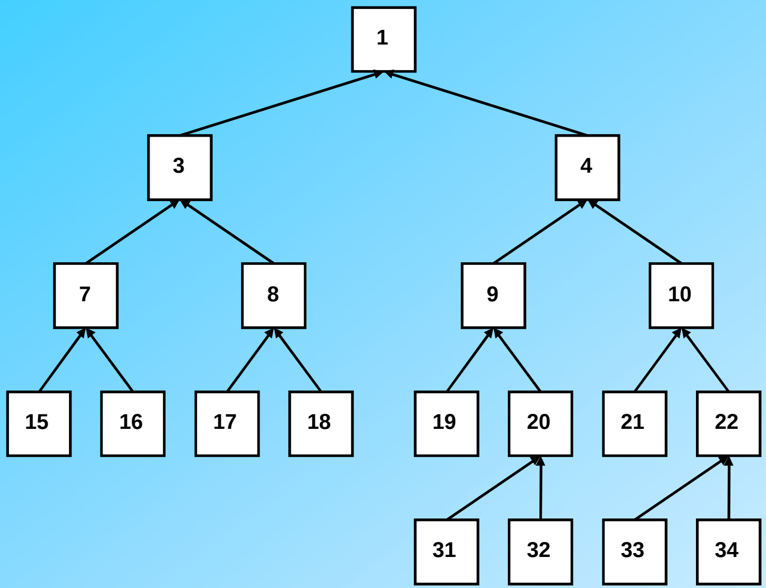
Experimental Design

	Level 1	***Level 2***
Setup Cost	Low (0.5)	High (12.5)
Targeted Capacity Utilization	50%	90%
Product Structure	General	Assembly

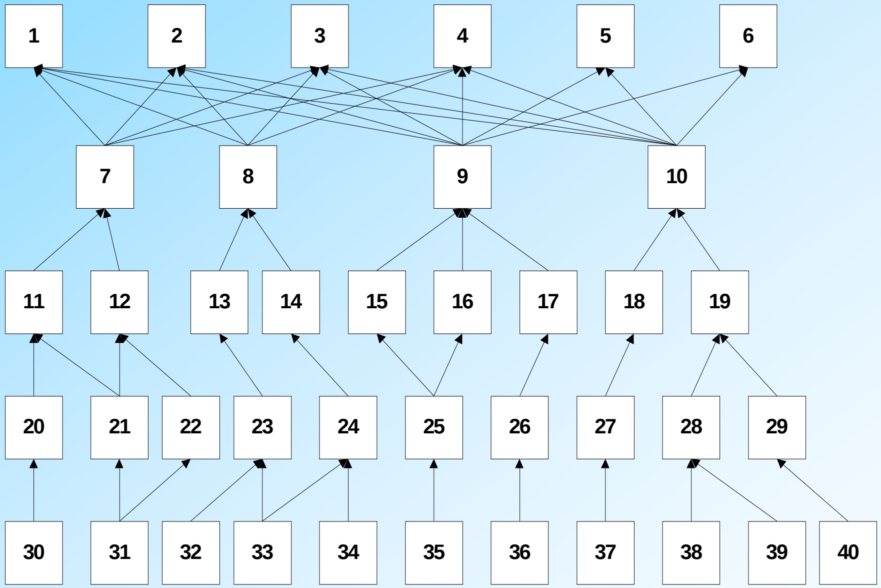
- 2^3 factorial design: three factors and two levels each
- Response variable: Schedule instability between first and second tiers only
  - $ST_t = CV(X_t^m)$
- For each production period, end item demand perturbed to generate 4 variates
- Test data set selected from 1200 problem instances[1]
  - 40 items, 6 facilities, 16 time periods, 5 supplier tiers

[1] *Test data source: Templemeier and Derstroff, 1996*

Product Structures



Assembly - no component commonality



General - with component commonality

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Analysis of Variance

	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
MAIN EFFECTS					
Product Structure	0.8052	1	0.8052	5.02	0.0319
Setup Cost	0.9019	1	0.9019	5.62	0.0237
Design Capacity	0.7292	1	0.7292	4.55	0.0405
INTERACTIONS					
Prod Strc x Setup Cst	0.1277	1	0.1277	0.80	0.3788
Prod Strc x Design Cap	0.4891	1	0.4891	3.05	0.0901
Setup Cst x Design Cap	0.0118	1	0.0118	0.07	0.7878
RESIDUAL	5.2930	33	0.1604		
TOTAL (Corrected)	8.3579	39			

All three factors and one interaction are significant at 90% significance level

Main Effects

Table of Least Squares Means
(95 percent confidence intervals)

Level	**Mean**	**Lower Limit**	**Upper Limit**
GRAND MEAN	0.4957		
Product Structure			
General	0.3538	0.1716	0.5360
Assembly	0.6376	0.4554	0.8198
Setup Cost			
Low	0.3455	0.1633	0.5277
High	0.6459	0.4637	0.8281
Design Capacity			
Tight	0.6307	0.4485	0.8129
Relaxed	0.3607	0.1785	0.5429

Supply chains with

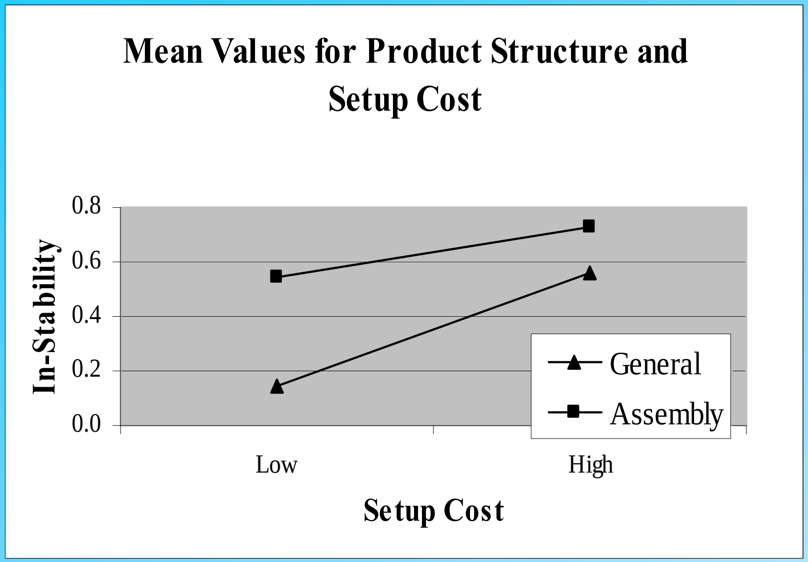
- *component commonality*

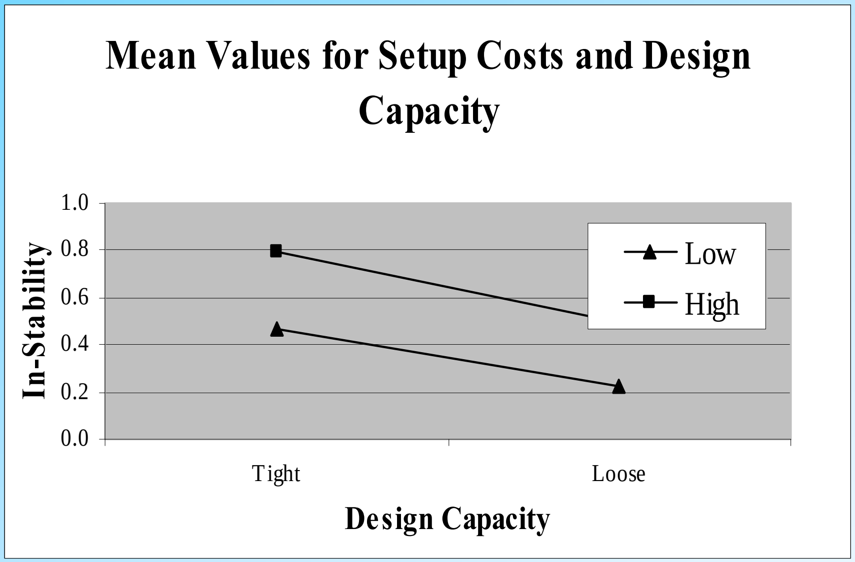
  or
- *low setup costs*

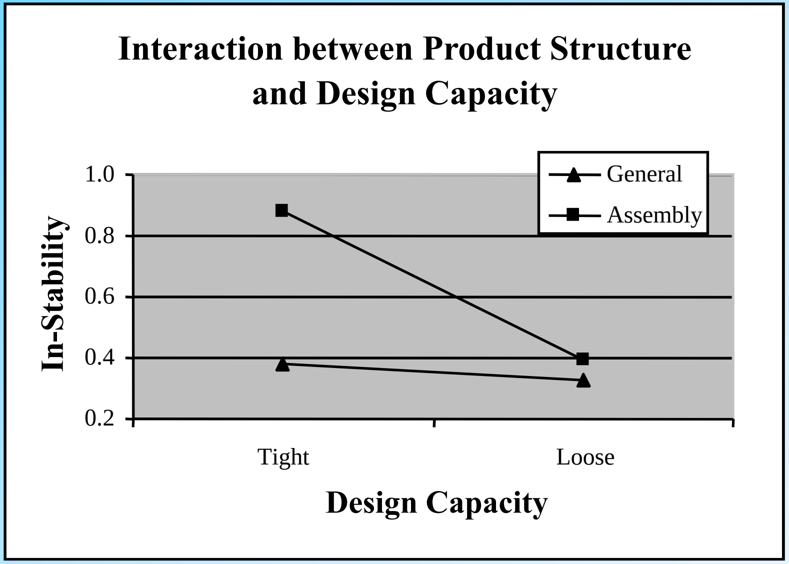
  or
- *relaxed capacity utilization*

tend to exhibit better schedule stability

Source: Meixell, M. J. (2005). “The Impact of Capacity, Commonality, and Batching on Schedule Stability: An Exploratory Study,” *International Journal of Production Economics* 95:1, pp 95-107.







General product structures (with component commonality) are beneficial regardless of design capacity

But…

Assembly product structures are detrimental with tight design capacity and beneficial with relaxed/loose design capacity.

Source: Meixell, M. J. (2005). "The Impact of Capacity, Commonality, and Batching on Schedule Stability: An Exploratory Study," *International Journal of Production Economics* 95:1, pp 95-107.

Table of Least Squares Means
(95 percent confidence intervals)

Level		Mean	Lower Limit	Upper Limit
Product Structure by Setup Cost				
General	Low	0.1472	-0.1105	0.4048
General	High	0.5605	0.3028	0.8181
Assembly	Low	0.5439	0.2862	0.8016
Assembly	High	0.7312	0.4736	0.9889
Product Structure by Design Capacity				
General	Tight	0.3783	0.1206	0.6359
General	Loose	0.3294	0.0717	0.5870
Assembly	Tight	0.8832	0.6255	1.1408
Assembly	Loose	0.3920	0.1343	0.6496
Setup Cost by Design Capacity				
Low	Tight	0.4634	0.2057	0.7210
Low	Loose	0.2277	-0.0300	0.4854
High	Tight	0.7981	0.5404	1.0557
High	Loose	0.4937	0.2360	0.7513

Beneficial Supply Chain Conditions

Detrimental Supply Chain Conditions

Source: Meixell, M. J. (2005). "The Impact of Capacity, Commonality, and Batching on Schedule Stability: An Exploratory Study," *International Journal of Production Economics* 95:1, pp 95-107.

Implications

- Setup costs influence schedule stability in a supply chain
  - High setup costs provide "incentive" for orders to move from one week to another in ensuing releases
- Capacity utilization influences schedule stability in a supply chain
  - With high capacity utilization, when capacity is reached for a particular production week, orders may be built ahead
- Component commonality (product structure) influences schedule stability in a supply chain
  - Un-correlated changes to multiple customer schedule releases will tend to cancel
- Even without controlling for schedule stability, performance can be managed through design factors