Logistics/Supply Chain & Energy Storage

Lessons learned from Inventory Management and Flexible Production

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Outline

• Drawing parallels in grand scale
• Demand Management
• Risk Management
• Inventory Management
• Flexible Production systems
• Drawing parallels in more details
• What is next?
Drawing parallels – Grand scale

How to manage demand & risks?
Demand Management

- Generate demand
  - Push system (from source to sink)
  - Pull system (from sink to source)
  - Just in Time (JIT) System

- Meet demand
  - Kanban control for inter-process regulation
  - Line balancing for flow regulation
  - Manufacturing Execution Systems (MES)
    - Day-ahead scheduling
    - Hourly scheduling
  - Manufacturing/Material Requirements Planning (MRP)
  - Enterprise Resource Planning (ERP)
    - Master scheduling
    - Resource mapping
Risk Management

• Demand Uncertainty
  – Storage mitigates demand surge risk

• Transport & Delivery Delays
  – Storage near delivery / customer mitigates risk

• Lost Sales & Contractual Penalties for Delays
  – Curtailment and Liquidated Damages

• Inventory carrying costs

• Inventory devaluation/depreciation
  – Perishable / seasonable goods; fashion shifts; price erosion

• Balancing Risks vs Cost of Mitigation
<table>
<thead>
<tr>
<th>Demand management</th>
<th>Logistics/SC</th>
<th>Power</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Kanban</td>
<td>Dispatching</td>
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<td></td>
<td>Line balancing</td>
<td>Energy regulation</td>
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<td></td>
<td>Manufacturing Execution System (MES)</td>
<td>Wholesale market design</td>
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<tr>
<td>Demand generation</td>
<td>JIT, push or pull</td>
<td>Used to be JIT, moving towards push+pull</td>
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<tr>
<td>Business risks</td>
<td>Retailer lost business</td>
<td>Load curtailment</td>
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<td>Risks and mitigation</td>
<td>Safety stock</td>
<td>Spinning reserve</td>
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<tr>
<td></td>
<td>Lead time</td>
<td>Delays/lost load due to wrong renewable forecast</td>
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<td></td>
<td>Inventory Buffer</td>
<td>Storage</td>
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<td></td>
<td>Dynamic rerouting</td>
<td>Dynamic switching</td>
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</tbody>
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A closer look @ parallels

Logistics/Supply Chain
• Flexible routing for reliability
• Long term supply contracts & short term case by case
• Supplier Redundancy

Power & Energy
• Inherent transmission network; switching in distribution
• PPAs, DA Market, Real Time / Spot Market
• Capacity Margin & Reserves

• Location, capacity & charge/discharging control of Inventory/storage
Inventory management

• **Why?**
  – Inter-process regulations; to dampen process variations & drifts
  – Safety stock to reduce shortage risks
  – Warehouse to store finished goods and raw materials
  – Arbitrage (for raw materials and finished goods)
  – Higher performance and throughput

• **How?**
  – Continuous monitoring & control (charging) according to EOQ or other control policies; discharge can be continuous or discrete;
  – Periodic monitoring & control according to EQO or other policies; discharge can be continuous or discrete;
  – Single period (Newsboy problem)

• **Where and how big?**
  – Location, Capacity & charge/discharging control of Inventory/storage
Examples (why & how?)

WIP

blockage

starvation

Flow of Material

RAW MATERIAL

Operation I

Operation II

Final Product

BUFFER

BUFFER

BUFFER

Safety Stock
• Proximity to population centers matter
• Location of distribution center makes a difference;

• Transportation cost in terms of person-miles (PM) for 1 distribution center in:
  – LA: 557,912 million
  – Chicago: 294,092 million
  – Pierre: 326,247 million
Location and Capacity (2)

- 2DCs: 195,986 million PM
Location & Capacity (3)

- 2DCs: 195,986 million PM
- 3DCs: 149,243 million PM
• 2DCs: 195,986 million PM
• 3DCs: 149,243 million PM
• 5DCs: 103,003 million PM
Cost of inventory vs location/capacity

**Variable Cost Only**

- Chicago: 300,000
- 2DC: 150,000
- 3DC: 100,000
- 5DC: 50,000

**Fixed and Variable Cost**

- Chicago: 300,000
- 2DC: 250,000
- 3DC: 200,000
- 5DC: 150,000

- Variable Cost
- Fixed Cost
More parallels – inventory vs storage

<table>
<thead>
<tr>
<th>Terminologies</th>
<th>Inventory control</th>
<th>Storage control</th>
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<tbody>
<tr>
<td><strong>Demand</strong></td>
<td>Quantity demanded per unit of time</td>
<td>Demand(t) = max {0, load(t) - transformer capacity}</td>
</tr>
<tr>
<td><strong>Shortage cost</strong> ($/unsatisfied demand)</td>
<td>Cost of lost sales</td>
<td>Penalty due to loss of load</td>
</tr>
<tr>
<td><strong>Setup cost</strong> ($/charge)</td>
<td>Component of ordering cost which does not vary with order amount</td>
<td>Battery capital cost per cycle</td>
</tr>
<tr>
<td><strong>Proportional order cost</strong> ($/unit)</td>
<td>Cost per unit</td>
<td>Average cost to charge</td>
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<tr>
<td><strong>Lead time</strong> (Hours)</td>
<td>Time interval between placing an order and receiving it</td>
<td>Battery duration</td>
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<tr>
<td><strong>Flow capacity</strong></td>
<td>Transportation capacity</td>
<td>Transformer capacity (for upgrade deferral)</td>
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</tbody>
</table>
Flexible Production System

- Flexibility to react to planned or unplanned (random) changes & failures;
  - *Machine flexibility*
    - Ability to produce new product types
    - Ability to change the order of operations executed on a part
  - *Routing flexibility*
    - Ability to use multiple machines to perform the same operation on a part
    - Ability to absorb large-scale changes in volume, capacity, or functionality
  - Small to medium size production batches
  - Significantly small set up times and costs
### Problems

<table>
<thead>
<tr>
<th>Flexible Manufacturing System</th>
<th>Energy Storage</th>
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</thead>
<tbody>
<tr>
<td><strong>Design</strong></td>
<td><strong>Storage sizing for multiple-use</strong></td>
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<tr>
<td>Capacity of material handling system, buffer size</td>
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<tr>
<td><strong>Planning</strong></td>
<td><strong>Day ahead commitment level for different applications</strong></td>
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<tr>
<td>Short term (one day): Parts mix ratio</td>
<td></td>
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<tr>
<td>Allocation of pallets and fixtures</td>
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<tr>
<td>Assignment of operations</td>
<td></td>
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<tr>
<td><strong>Scheduling</strong></td>
<td><strong>Optimal control of charging and discharging of storage</strong></td>
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<td>On-day:</td>
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<tr>
<td>Optimal sequence of inputs</td>
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<td>Optimal machine output</td>
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Lessons learned

• It works.
• Very mature with many simple and intelligent solutions (e.g., EOQ and r&R policy).
• Commercial solution packages for intelligent inventory management across large networks of suppliers, distribution centers, and points of sales.
• Uses demand forecasts but is usually robust to random noises.
• System intelligence is the key!
What is next?

- Multi-objective use of storage
  - Substation upgrade deferral
  - Substation transformer life extension
  - Loss reduction
- Optimal storage size and location
- Doing better with a smaller storage unit

- Reduce Capital Costs and cycle Losses
- Reduce Risk of Premature Failure
- Better manage capacity expansion deferral (substation)