Inventory optimization
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Optimize  Design  Experiment  Innovate
Inventory optimization challenges

The analytical approach to inventory optimization: pros & cons

Simulation-based inventory optimization:
  – Safety stock estimation: taking into account operational and disruptive risks.
  – Multi-echelon inventory management: considering stocks across the whole supply chain, including multi-tier demand.
  – Capturing the complex behavior of supply chains

Q&A session
Inventory optimization challenges
What is stock

• **Inventory**, or **stock**, is the goods and materials that a business holds for the ultimate goal of resale

• Stocks are evil:
  – No profitability until they are sold
  – Possession costs
  – Frozen assets
  – Need storage area
  – Maintaining and handling

• Stocks are good:
  – Ultimate goal is to provide required service level for end customers or production

• The main objective of inventory management:
  – Find the balance between good and evil
There are different kinds of stock

• Keep the operations going
  – Raw materials stock
  – Work-in progress stock
  – Maintenance, repairs and operations

• Financial saves
  – FTL transportation policy
  – Supplier discounts
  – Batch production

• Demand driven stock
  – Stock for peak season
  – Safety stock to provide required service level
  – Stock to mitigate risks

• Other
  – Stock for future price changes
  – Simplified/periodic inventory review policies
  – …
How demand affects stocks

• **Demand**
  – Period: 1 day
  – Quantity: 10

• **Supply**: 4 days

• **Inventory Policy**
  – Reordering point: 40
  – Order size: 80

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**Ideal Inventory**

**Constant demand**
How demand affects stocks

- **Demand**
  - Period: 1 day
  - Quantity: \texttt{normal(10,4)}

- **Supply**: 4 days

- **Inventory Policy**
  - Reordering point: 40
  - Order size: 80

![Graph showing variable demand and inventory with variable demand]
How demand affects stocks

- **Demand**
  - Period: 1 day
  - Quantity: 10

- **Supply:** 2-5 days

- **Inventory Policy**
  - Reordering point: 40
  - Order size: 80
How demand affects stocks

• **Demand**
  – Period: 1 day
  – Quantity: normal(10, 4)

• **Supply**: 2-5 days

• **Inventory Policy**
  – Reordering point: 40
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The analytical approach to inventory optimization: pros & cons
Traditional approaches to a stock management

• Simple (guessing)
  – Stock finished goods for 15 days of demand
  – Stock raw materials for 1 month of production

• Analytical
  – Consider supply chain as a mathematical model
  – Calculate stock based on input parameters (e.g. service level)

• Best practices (experience)
  – Implement working rules without any improvements

• Outsourcing (I want to believe)
  – Integrate an Inventory management system with no detailed knowledge about how it works
Analytical approach

- **Demand**  
  - Period: 1 day  
  - Quantity: \textit{normal}(10,4)

- **Supply**: 4 days

- **Inventory Policy**  
  - Reordering point: 40  
  - Order size: 80

\[
SS = Z_\alpha \cdot \sqrt{E(L)\sigma^2_D + (E(D))^2\sigma^2_L}
\]

\[
= 13.2
\]
Analytical approach

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\[
SS = Z_\alpha \times \sqrt{E(L)\sigma_D^2 + (E(D))^2 \sigma_L^2}
\]

We do not know the actual distribution for lead time!
Analytical approach: cons

- Demand and supply time supposed to be normally distributed
  - Real demand and supply time cannot be negative
  - Need to find distribution parameters from history/forecast
  - Actual distribution is not necessarily normal

- All values supposed to be independent

- Different calculation for each “season”

- Multi-tier supply chain
  - Single-echelon optimization for each tier
  - Demand propagated upwards from lowest tier
  - Replenishment strategies are applied to one tier without regard to its impact on the other tiers
Analytical approach: cons

• It’s almost impossible to consider complex Supply Chain behavior, such as:
  – Returns
  – Additional processing time depending on order size
  – Complex inventory policies (like MRP)
  – Policies with periodic review
  – Variation or conditional behavior within the supply chain
Simulation-based inventory optimization
What is Dynamic Simulation Modeling

- A Simulation model is described as a set of **logical rules**
  - Customer places orders for 300 units per day 4 days a week
  - Initial inventory is 3000. If inventory is below 2000 the DC orders a batch of 3000 units
  - If factory has enough orders for 3000 units then production is started
  - If supplier workers are on strike it will not process the orders
  
- Simulation is the process of executing the **logical rules** over time
  - If raw materials stock drops below 100m³ order 300m³

- The output of a simulation is the behavior of a system over time
  - Customer places orders for 300 units per day 4 days a week
  - Initial inventory is 3000. If inventory is below 2000 the DC orders a batch of 3000 units
  - If factory has enough orders for 3000 units then production is started
  - If supplier workers are on strike it will not process the orders
Dynamic simulation advantages

• No need for formulas
• Reproduce supply chain behavior in time
• Work with individual orders and shipments, not averages
• Capture all supply chain details
  – Polices
  – Fleets
  – Variability
  – Decisions
  – Schedule
• Easily scalable and adjustable
How ALX Performs Inventory Optimization

- **Quantity**
  - "Reorder up to" quantity
  - Reorder point

- **Simulation modeling time**
  - Safety stock to provide 100% service level
  - Redundant safety stock
  - Actual inventory behavior
  - Ideal inventory dynamics

Safety stock to provide 100% service level
Safety stock estimation

• Demo #1: Operational risks
  – Demand variability
  – Lead time variability

• Demo #2: Disruption risks
  – Supplier shutdown
Multi-echelon Inventory Management

• **Goal:**
  - To deliver the desired end customer service levels with minimum inventory investment among the various echelons

• **Requirements for true multi-echelon inventory optimization**
  - Avoid multiple independent demand forecasts in each echelon
  - Account for all lead times and lead time variations
  - Monitor and manage the bullwhip (variability) effect
  - Enable visibility throughout the supply chain
  - Account for various replenishment strategies

• **Demo #3: Multi-tier supply chain**
  - To satisfy all of the above requirements ALX uses simulation modeling to perform inventory optimization
Capturing the complex behavior of supply chains

- Dynamic simulation allows to describe all Supply Chain behavior, such as:
  - Complex polices (MRP, periodic review polices)
  - Limited resources (fleet, storage)
  - Customers behavior (ELT, returns)
  - Seasonality
  - Any other

- Demo #4: MRP policy
  - The purpose of Material Requirements Planning in the model is the daily generation of orders and orders expectations based on forecasted inventory and safety stock levels
Another possibilities

- Compare costs and Service Level with different inventory policy parameters

<table>
<thead>
<tr>
<th>Description</th>
<th>Service Level by Products</th>
<th>Total Cost</th>
</tr>
</thead>
<tbody>
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<td></td>
<td>mean</td>
<td>min</td>
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<td>r: 60</td>
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<td>0.885</td>
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<tr>
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</table>
Another possibilities

- Compare carrying costs vs transportation costs with different batch sizes

<table>
<thead>
<tr>
<th>Iteration</th>
<th>Description</th>
<th>Inventory Carrying Cost mean</th>
<th>Total Cost mean</th>
<th>Transportation Cost mean</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>Iteration 1</td>
<td>23,940</td>
<td>50,756.815</td>
<td>23,261.815</td>
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<td>2</td>
<td>Iteration 2</td>
<td>26,088</td>
<td>52,661.815</td>
<td>23,021.815</td>
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<td>54,357.815</td>
<td>23,361.815</td>
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<tr>
<td>4</td>
<td>Iteration 4</td>
<td>31,520</td>
<td>58,221.815</td>
<td>23,181.815</td>
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<tr>
<td>5</td>
<td>Iteration 5</td>
<td>27,240</td>
<td>53,781.815</td>
<td>23,031.815</td>
</tr>
</tbody>
</table>
Another possibilities

• Define production or supply schedule based on demand and inventory polices
And much more...

• Visibility of any metric in the Supply Chain
  – CO2 emission
  – Resources utilization
  – Lead times

• All details captured
  – Production process
  – Fleet
  – Schedules

• Integration with business processes
  – Digital twin
  – Control tower
Upcoming events

March 7, 2019 - anyLogistix Seminar (in Japanese) - Kawasaki, Japan
March 18-20, 2019 - anyLogistix Training - Saint Petersburg, Russia
March 28, 2019 – Free Transportation Optimization webinar - Online
April 3-5, 2019 - anyLogistix Training - Oakbrook Terrace, IL, USA
April 17-18, 2019 - The AnyLogic Conference - Austin, TX, USA