Discrete Event Simulation of Continuous Review (Q,R) Inventory Policy

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Roadmap

- Problem Statement
- Objective
- Explain Simulation
- Steps
- Output
- Key Takeaways & Managerial Insights

Problem

- The objective of inventory is to achieve satisfactory levels of customer service while keeping inventory costs within reasonable bounds.

- This is called **Inventory optimization** which is critical in supply chain management

- **But the complexity of real-world multi-echelon inventory systems under uncertainties results in a challenging optimization problem, too complicated to solve by conventional mathematical models.**

Objective

1. We propose a novel **simulation-based optimization framework** for optimizing inventory systems that operate on **multi-period inventory management** with **continuous review (Q, R) inventory policy**.

2. **The objective is to minimize the inventory cost while maintaining acceptable service levels.**

Multi Period Inventory Management … 1

1. The inventory system operates continuously with many repeating periods or cycles.

2. The lead time (L) for a new order is a random variable in general, reflecting the variation of delivery time.

3. The daily demand is Di (i = 1, …, L) within the lead time, where the D0 are also random variables, reflecting the variation of demand over time.

4. Inventory can be carried from one period to the next.

Multi Period Inventory Management … 2

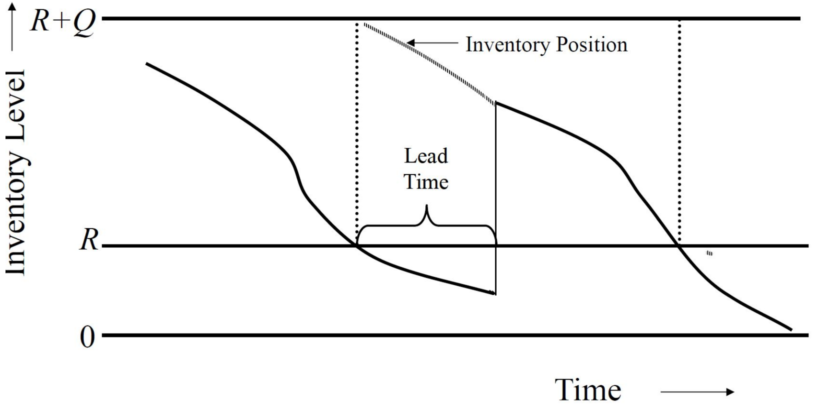
1. New orders can be placed based on one of the following two basic classes of reorder policies:

    a. **Event-driven:** These are reorder policies that are driven by reorder point (ROP) - **continuous review policy:** in which inventory is reviewed every day and a decision is made about whether and how much to order.

    b. **Time-driven:** These are reorder policies that are driven by time - **periodic review policy:** in which inventory is reviewed at regular intervals and an appropriate quantity is ordered after each review.

Continuous Review (Q, R) Inventory Policy

1. Whenever the inventory level reaches the reorder point R, place an order of Q to bring the inventory position to the order-up-to level R + Q.



2. Two decision to be made in the policy:
    a. Decide the reorder level R - **when-to-order**
    b. Decide the reorder quantity Q and hence the order-up-to level - **how much to-order.**

3. The two decision should be made based on the simulation results, to find the optimal Q, by minimizing the total inventory cost with the constraint of service level at 95%.

1. Assumptions
    a. Continuous Review (Q, R) inventory control policy
    b. There is an inventory holding cost (m.u./unit/day)
    c. There is fixed order cost (m.u./order)
    d. No backorders: when there is a stockout, the order is lost
    e. Random customer order demands
    f. Random order lead times

2. Given
    a. Unit holding cost and unit reorder cost
    b. Probability distributions for the random parameters

3. Determine
    a. Reorder point and optimal order quantity

4. Objective of the Simulation
    a. To minimize the inventory cost (= holding cost + reorder cost)
    b. To maintain service level no less than the minimum desired values

Benefits of a simulation model

- Basic models such as the EOQ model assume that the demand for each period is constant and the lead time is not fluctuating. Further they fail to consider lost sales.

- Simulation has the capacity of drawing samples through the creation of artificial observations that behave like random events in the real system.

- Simulation can be used to investigate quickly the effects of a change in a real life situation that takes place over several years and thus can be used to study complex systems.

Discrete Event Simulation(DES) Model

Main reasons to use DES are:

1. Possibility to include dynamics
2. Simplicity of modelling

DES model follows a set of rules about the actual operations-

Algorithmic: Includes set of steps for algorithm

Mathematical: Includes a set of equations for variable relationships

Logical: Includes a set of conditions that define the control of the system dynamics

Steps(1/3)

Step 1 - Create vector values for **Q** and **R**

Step 2 - Create a numeric variable : **CurrentInventory**

- Set it to initial estimated value

Step 3 - Create a logical variable : **Ordered**

- Set the initial value to False

Step 4 - Create a numerical value: **Lead**

- Set initial value to zero

Step 5 - Create a numerical variable: **Missed**

- Set initial value to Zero

Steps(2/3)

For given value of Q and R,

Step 6 - Calculate Lead Time using condition:

- IF **Ordered** = TRUE & Lead > 0, Reduce Lead by 1

Step 7 - Receive Delivery using the condition

- IF **Ordered** = TRUE & Lead = 0,
    - Increment **CurrentInventory** by **Q** & Set **Ordered** = FALSE

Step8 - Use **Inventory** : Randomly generate **Demand** from demand data

8.1 IF **CurrentInventory** > **Demand**

- Reduce **CurrentInventory** by the **Demand** quantity

8.2 IF **CurrentInventory** < **Demand**

- **CurrentInventory** to zero
- Augment Missed - difference in **Demand** and **CurrentInventory**

Steps(3/3)

Step 9: **Order Inventory:**

- IF **CurrentInventory** <= R
  - Set **Ordered** = TRUE.
  - Randomly assign a sampled value lead-time distributions to Lead
  - Compute Total Ordering cost by adding variable cost

Step 10: Compute inventory holding cost

- Add to a variable having total Inventory holding cost

Step 11: Compute Total missed opportunities & Service level

- **ServiceLevel** = (sum(**D**) - Miss)/sum(**D**)

Step 12: Repeat steps 6 through the previous step for all values of Q and R

Advantages & Challenges of DES Model

Major Advantages

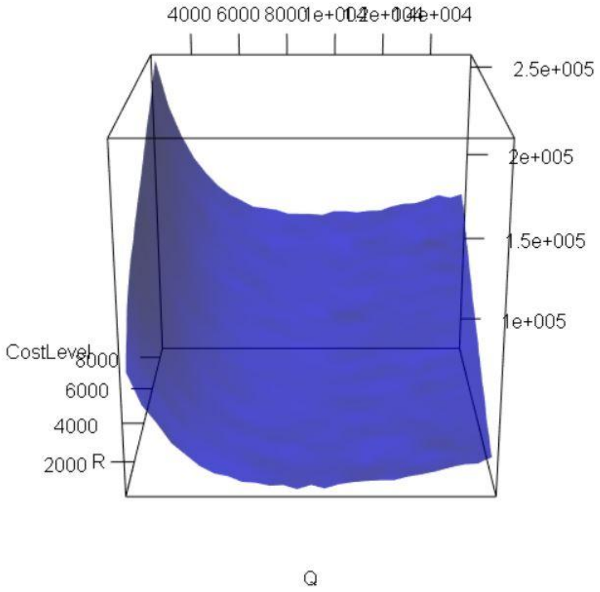
- Study new designs without interrupting real systems & understand existing
- Provides decision frameworks that are realistic and robust
- Visualize and understand system dynamics
- Uses actual system level logical or mathematical models and minimizes artificial assumptions or usage of stylized models
- Perform What-if kind of analysis for decision framework

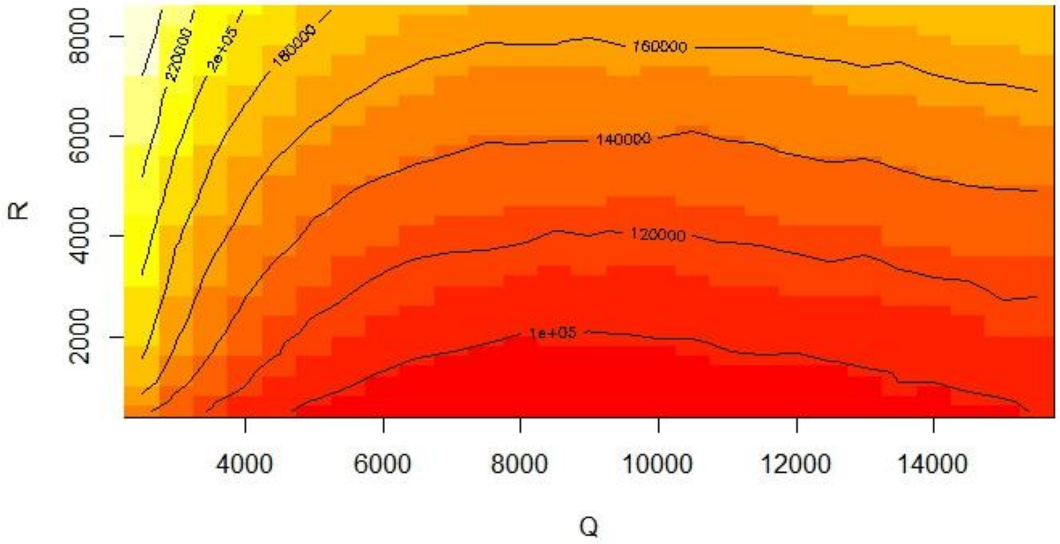
Challenges:

- Validation of Supply Chain could be difficult with lack of data
- Missing support for logistics process in simulation

Output

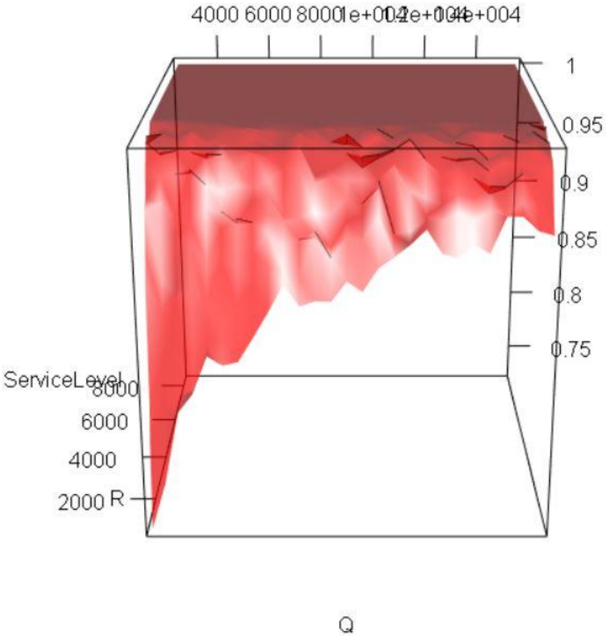
Different Views of Cost Profiles for Different Q and R Combinations

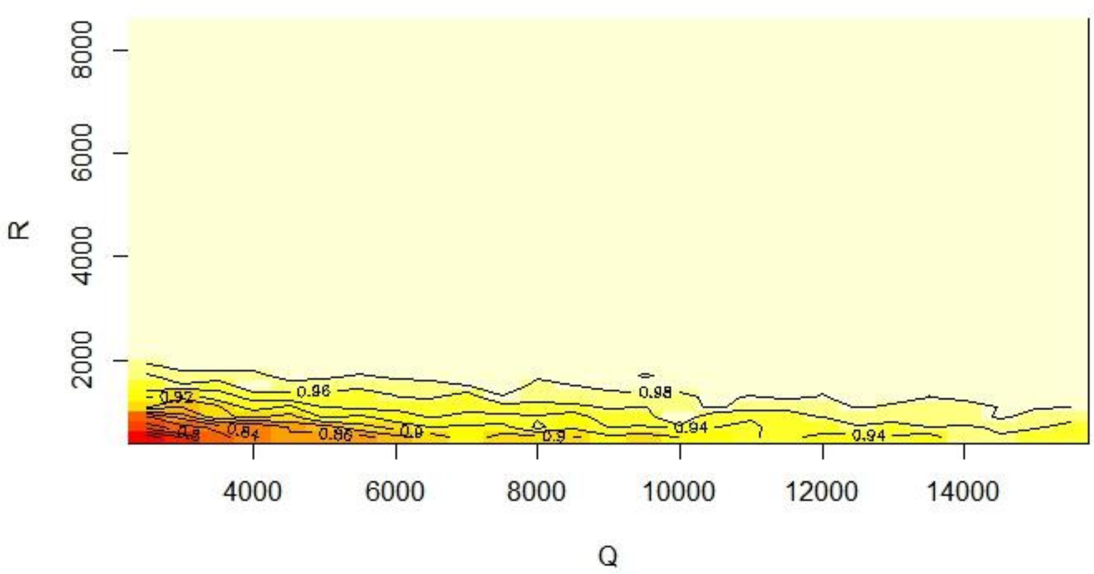




Output

Different Views of Service Levels for Different Q and R Combinations





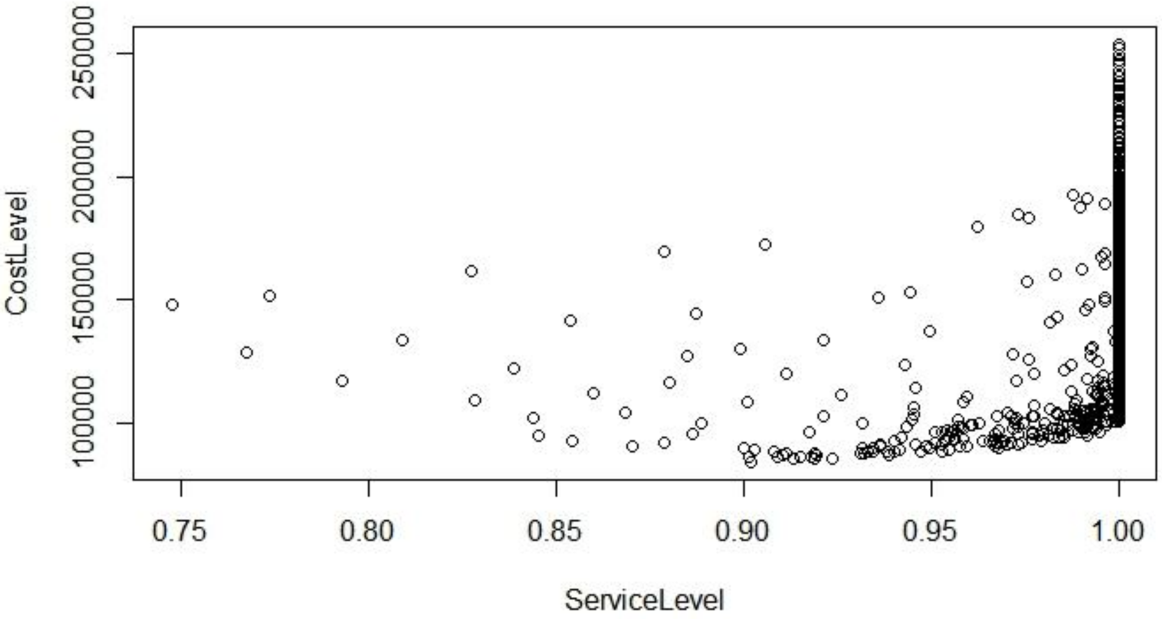
Output

Optimal Q & R for given service level and minimum cost level

Service Level	Minimum CostLevel	Optimal Q	Optimal R
1	$ 98,212	11000	1500
0.99	$ 93,202	10500	1100
0.98	$ 90,224	10000	900
0.97	$ 90,893	10000	1100
0.96	$ 89,109	9000	1100
0.95	$ 88,441	9000	900

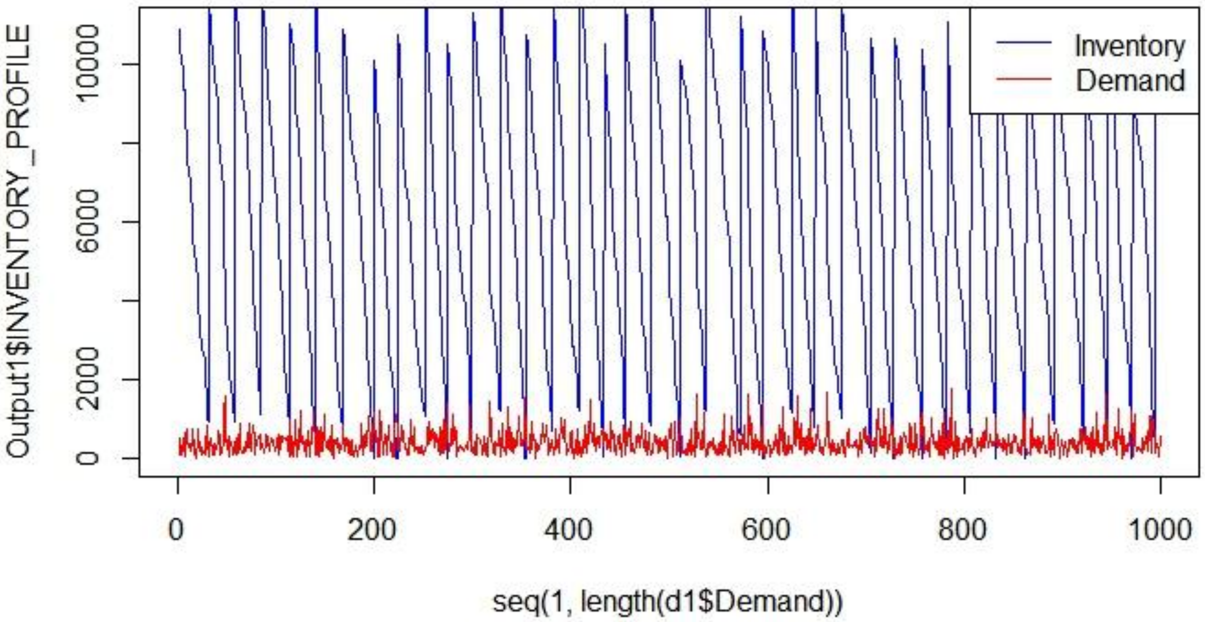
Output

Plot of Cost and Service Level



Output

Inventory Profile for Q = 11000, R=1500



Key Takeaways

- ➢ Inventory Decision Questions - How Much? When? - are answered
- ➢ EOQ under this model acts as good approximation
- ➢ Inventory optimization model can be used to find optimal inventory levels on safety stock targets
- ➢ Implementing simulation in inventory optimization, retailers and supermarkets can understand shelf-life, lead time, and replenishment rules

THANK YOU