MSBA 7004
Operations Analytics

Second-half course recap

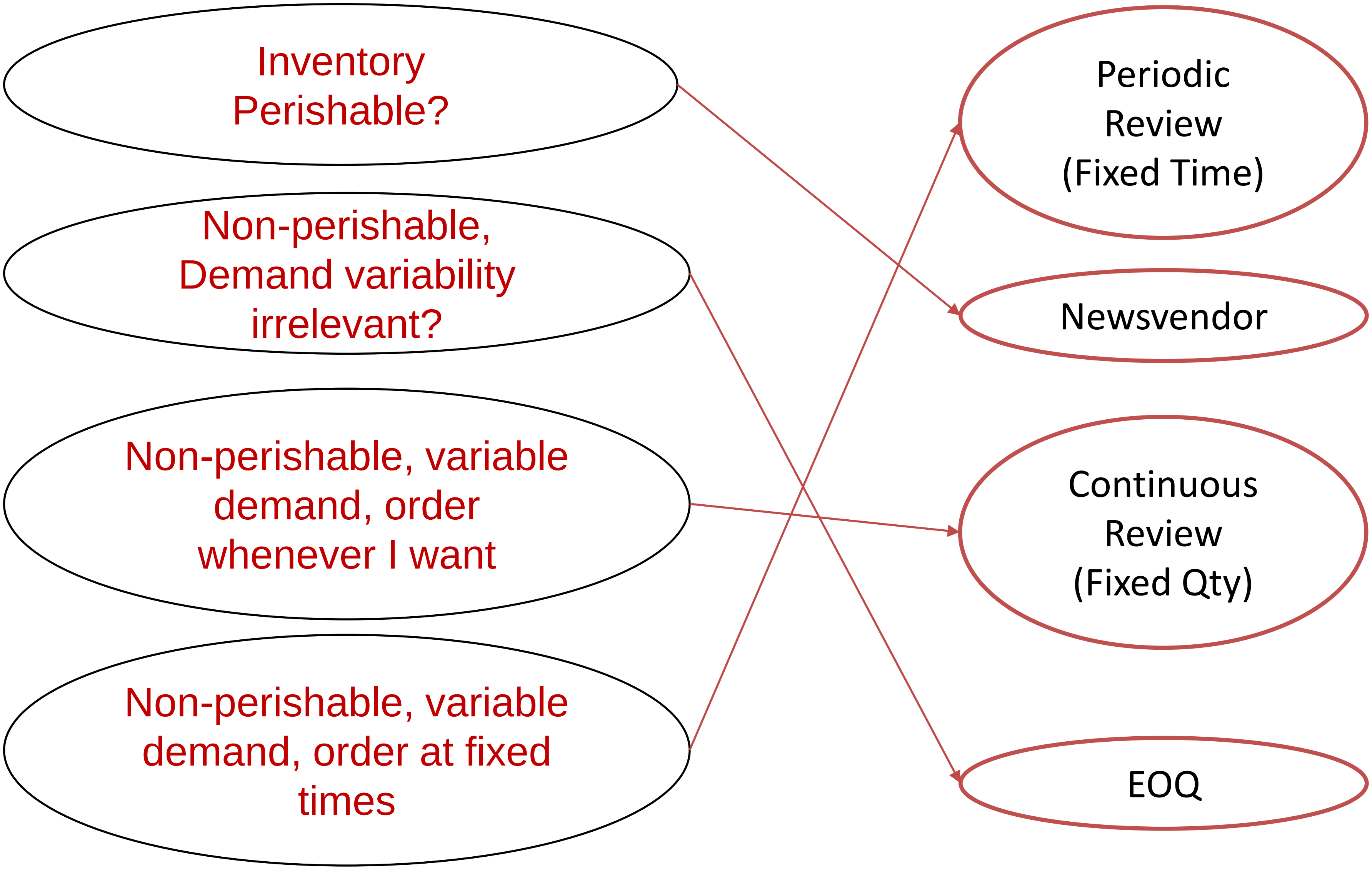
2023

Management Options

- Managing supply
  - Capacity management
    - Process (bottleneck) analysis
    - Queueing analysis
  - Inventory and supply chain management
  - Project management

- Managing demand
  - Revenue management

Inventory management



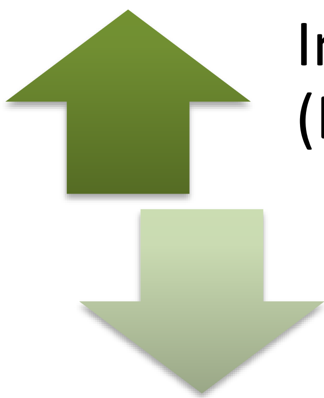
Match the inventory model with the decision.

- EOQ model
- Periodic review
- Continuous review
- Newsvendor

- Reorder point
- Target stock level
- Order quantity
- Lot size/order frequency

Economic Order Quantity (EOQ) Model

- How much to order each time?
- The Economic Order Quantity (EOQ) balances



Inventory ordering costs
(Economies of scale)

Inventory holding costs

- <u>Assumptions</u>
  - Known annual demand, constant demand rate
  - No uncertainty (in demand)

True or False?

The motivation of the EOQ model is to match the demand with the right quantity of supply.

Economic Order Quantity

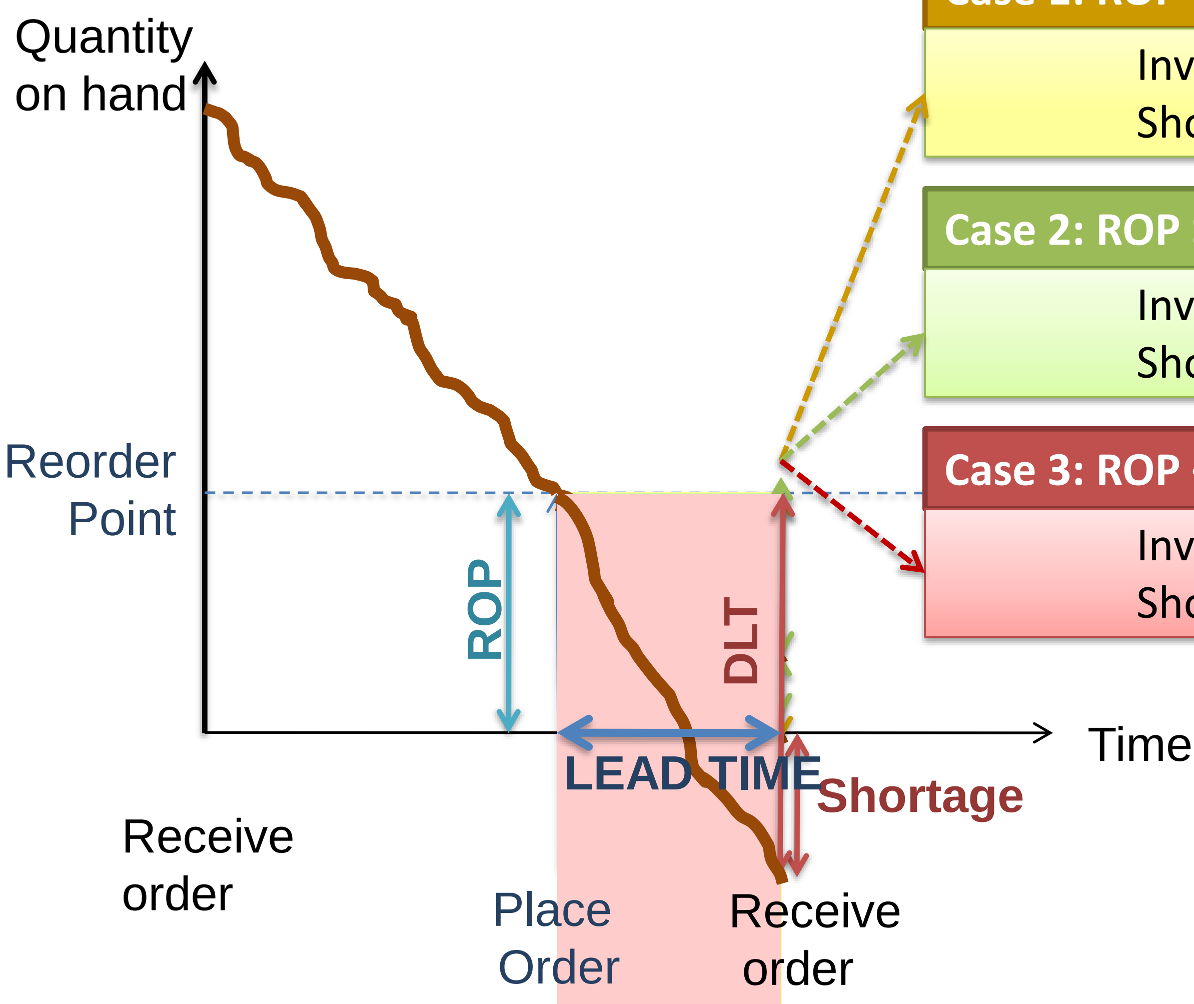
$$\text{Total Cost} = TC(Q) = \frac{Q}{2}H + \frac{D}{Q}S$$

D	Annual Demand Rate
S	Order or Setup Cost
H	Annual Holding Cost

$$Q_{OPT} = \sqrt{\frac{2SD}{H}}$$

$$TC_{OPT} = \sqrt{2SDH}$$

Demand During Lead Time: Uncertain



Case 1: ROP = DLT

Inventory = 0
Shortage = 0

Case 2: ROP > DLT

Inventory = ROP – DLT
Shortage = 0

Case 3: ROP < DLT

Inventory = 0
Shortage = DLT - ROP

DLT = Demand during the Lead Time

ROP and Normal Demand

Suppose weekly demand has a normal distribution: $N(m, \sigma^2)$

Suppose lead time is *k* weeks.

Then, DLT has normal distribution $N(m_{LT}, \sigma_{LT}{}^2)$

with mean $m_{LT} = k \cdot m$ and standard deviation $\sigma_{LT} = \sqrt{k} \cdot \sigma$

Given ROP, CSL is

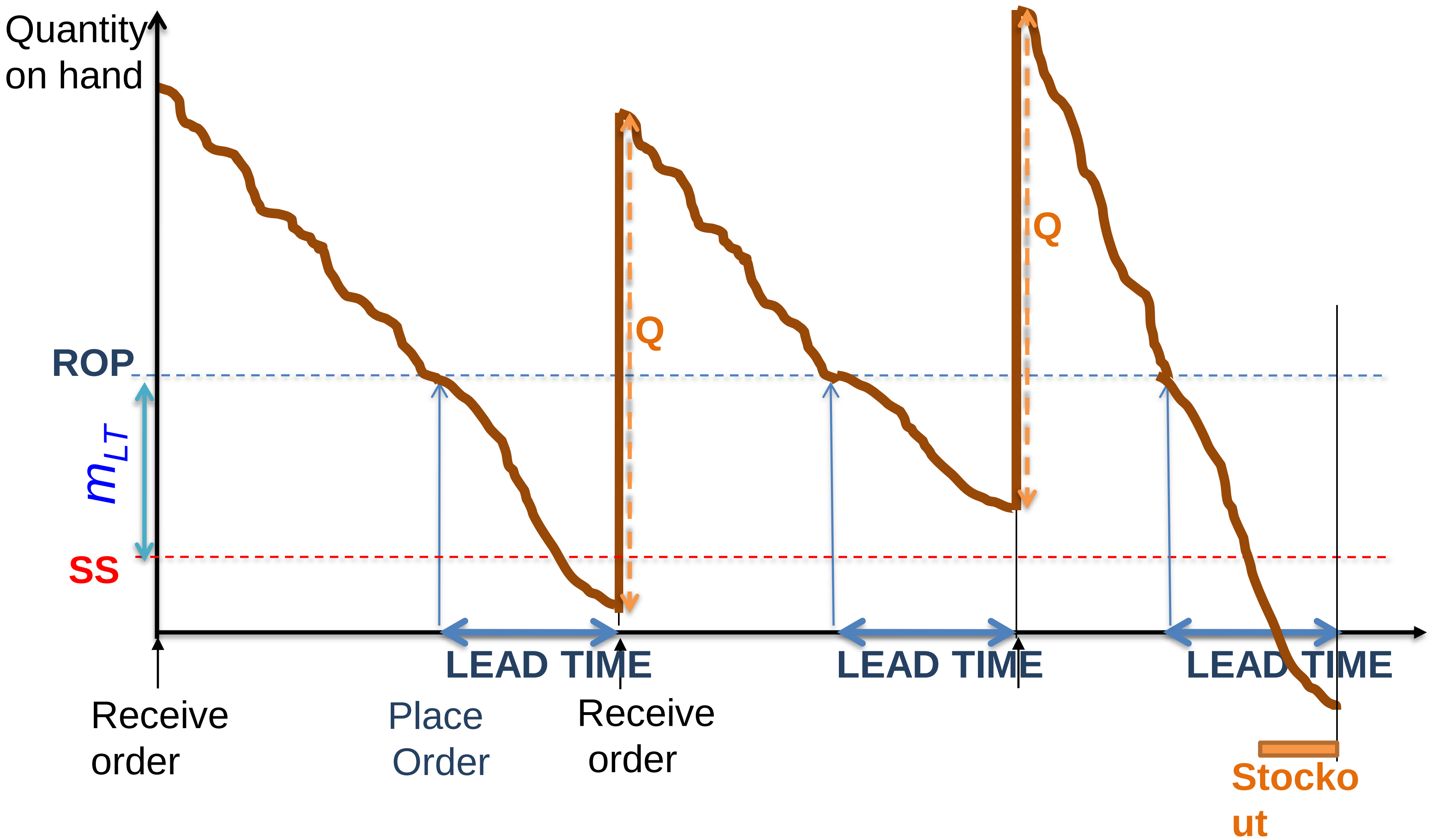
$P[DLT \le ROP] = P[N(0,1) \le z] = normsdist\ (z)$ where $z = \dfrac{ROP - m_{LT}}{\sigma_{LT}}$

Given CSL, *ROP* satisfying $\mathrm{CSL} = P[DLT \le \mathrm{ROP}]$ is

$\mathrm{ROP} = m_{LT} + z \cdot \sigma_{LT}$ where z=*normsinv*(CSL)

Safety Stock (SS)

ROP and SS



Quantity on hand
ROP
m_{LT}
SS
Q
Q
LEAD TIME
LEAD TIME
LEAD TIME
Receive order
Place Order
Receive order
Stockout

Average Inventory

If the firm pays for inventory "in stock"	If the firm pays for inventory "in stock" and "on route"
Average Inventory = Q/2 + SS	Average Inventory = Q/2 + SS + m_{LT} Pipeline Inventory

↑ "Default" case in this course
(when there is no other explanation)

Order Size for Fixed-Time-Period Model

Assume Normal demand uncertainty

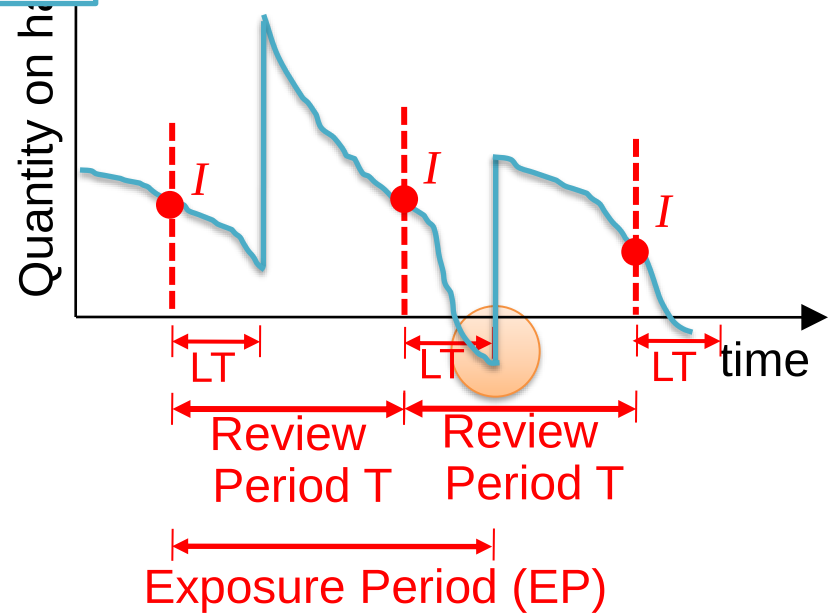
Given Cycle service level (CSL), we can find z = normsinv(CSL)

σ_{LT+T} Standard deviation of demand during the **exposure period**

Target Level or Target "Inventory Position"
= (LT + T) * D + $z\sigma_{LT+T}$

Order Quantity
= Target Level - I

I	Current inventory
T	Review Period (time between reviews)
EP	**Exposure Period** (= LT+T)



Practice problems

1. Kristen believes they are currently holding too much inventory for some ingredients, and she decides to optimize the inventory policy for whole wheat flour first using what she just learned from the Operations Analytics course. Kristen and her roommate bake cookies 7 days a week all year round. They get deliveries of flour from Flour Foods Co. each Friday and pay for the food upon delivery. They must place orders on Monday to ensure the Friday delivery (i.e., order lead time is 4 days). Kristen has observed that weekly demand for whole wheat flour is normally distributed with a mean of 66 lbs and a standard deviation of 6.6 lbs. Because she is a regular customer, Flour Foods Co. waives delivery charges. However, each package of flour is 10 lbs (i.e., order size must be multiples of 10 lbs).

- Suppose that on Monday, Oct 18, Kristen checked her whole wheat flour inventory and found that she had 83 lbs in stock. How much whole wheat flour should she order to maintain a 99% service level?

$D = 66$ lbs. per week

$\sigma = 6.6$ lbs. for weekly demand

$SL = 99\%$

$T = 1$ week

$LT = \frac{4}{7}$ week

$Iventory = 83$ lbs.

Thus:

$z = normsinv(SL) = 2.33$

$\sigma_{LT+T} = \sqrt{LT+T} \cdot \sigma = 8.27$

Target: $(LT+T) \cdot D + z\sigma_{LT+T} = 122.96$

Order Quantity: $Target - Inventory = 39.96$ lbs.

Therefore, Kristen should order 4 packages of flour to maintain a 99% service level.

Practice Problems

2. Kristen also orders paper take-out bags with her logo printed on them. Daily demand for take-out bags is normally distributed with a mean of 50 bags and a standard deviation of 20 bags. Kristen places a new order for bags whenever she is running low. Kristen's printer (company) charges her $15 per order for print setup independent of order size. Bags are printed in batches of 100, and priced at $5 per batch (i.e., 5 cents each bag). It takes 5 days for an order to be printed and delivered. The only holding cost is the opportunity cost of capital, which is estimated to be 30% per year. Assume 360 days per year.

a) What is the optimal order quantity per order for Kristen?
b) On average, how often does Kristen need to order take-out bags? That is, if Kristen places an order once every X days, what is X?
c) If Kristen wants to make sure the bags do not run out with 99% probability during the order lead time, what is her optimal reorder point?

a

$D = 0.5 \times 360$ batches per year

$S = \$15$

$C = \$5$

$I = 30\%$

Hence, $Q_{OPT} = \sqrt{\frac{2SD}{I \cdot C}} = 40$ batches.

b. $X = \frac{Q}{D} = 80$ days

c.

$SL = 99\%$

$k = 5$ days

Average daily demand $m = 0.5$ batches

$\sigma = 0.2$ batches for daily demand

$m_{LT} = km = 2.5$ batches

$\sigma_{LT} = \sqrt{k} \cdot \sigma = 0.45$

$z = normsinv(SL) = 2.33$

Hence, to maintain a 99% service level, $ROP = m_{LT} + z\sigma_{LT} = 3.54$ batches.

How much inventory should you hold?

- Trade-off #1: How much to order each time?

Inventory ordering costs
(Economies of scale)

Inventory holding costs

Economic Order Quantity (EOQ) Model

- Trade-off #2: How much to hold each time?

Cost of running out

Cost of having excess inventory

Newsvendor Model

What is the Best Service Level (SL*) ?

- Trade-off:

	Inventory Holding Cost (Overage Cost)	Loss of Revenue & Goodwill (Underage Cost)
High Service Level	High	Low
Low Service Level	Low	High

How to Interpret C_u and C_o?

C_u , C_o are the unit opportunity costs.

You should compute C_u:

Suppose the actual demand D is larger than my current stock S. If I could return to the past and order one unit more, then it increases my profit (or reduces my cost) by C_u.

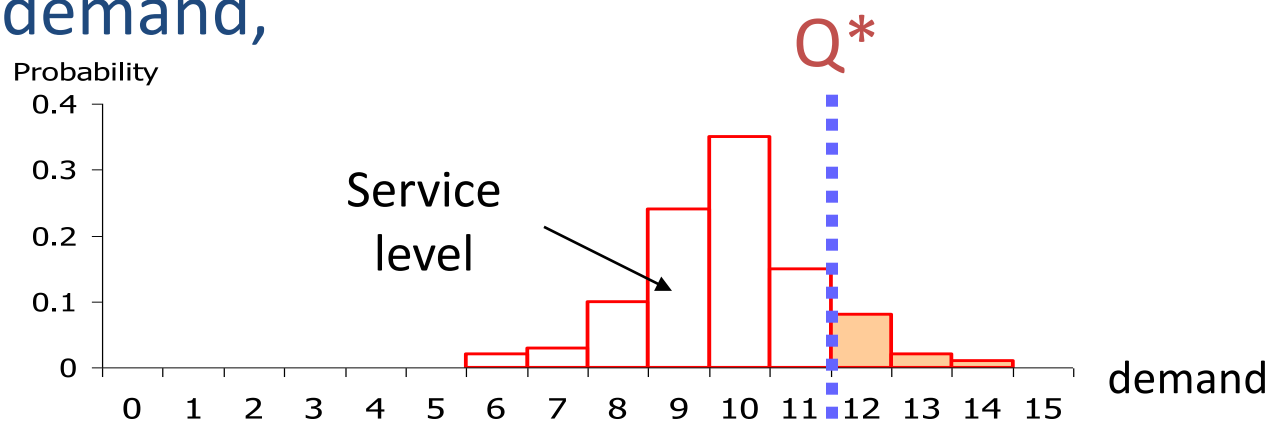
You should compute C_o:

Suppose the actual demand D is smaller than my current stock S. I could return to the past and order one unit less, then it increases my profit (or reduces my cost) by C_o.

Newsvendor logic

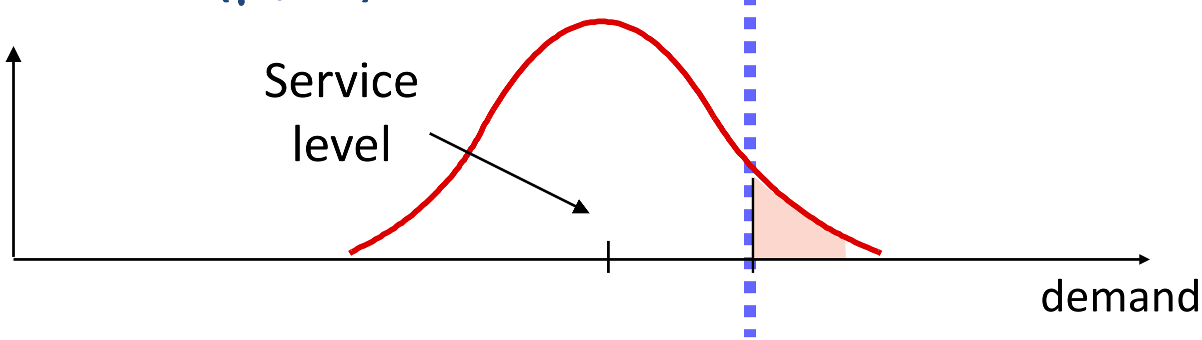
- With discrete demand,

Q^* = smallest quantity such that $SL \geq C_u / (C_u+C_o)$



- With normal demand $N(\mu, \sigma)$

Q^* = the quantity such that $SL = C_u / (C_u+C_o)$

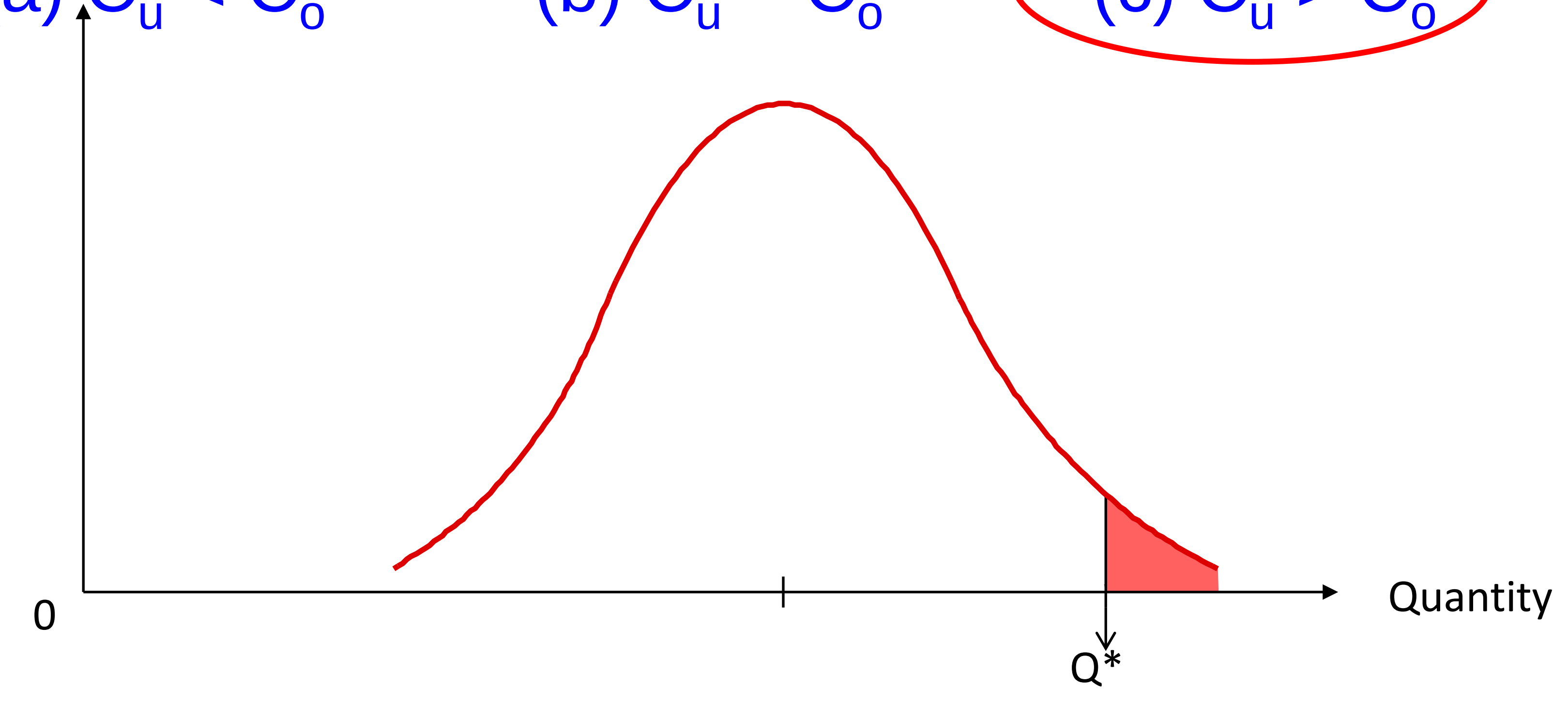


Step 1: find z, $z = \text{NORMSINV}(C_u / (C_u+C_o))$, or use z table

Step 2: compute Q^*, $Q^* = \mu + z\,\sigma$

In the newsvendor problem, suppose the demand distribution and the optimal stocking level Q* are as shown. How do you think C_u and C_o compare?

(a) $C_u < C_o$ (b) $C_u = C_o$ (c) $C_u > C_o$



Example 1: Newsvendor Model with Normal Demand

For the academic year 2020-2021, demand for HKU T-shirts is normally distributed with mean 1000 and standard deviation 200.

Cost of shirts is $10.

Selling price is $15.

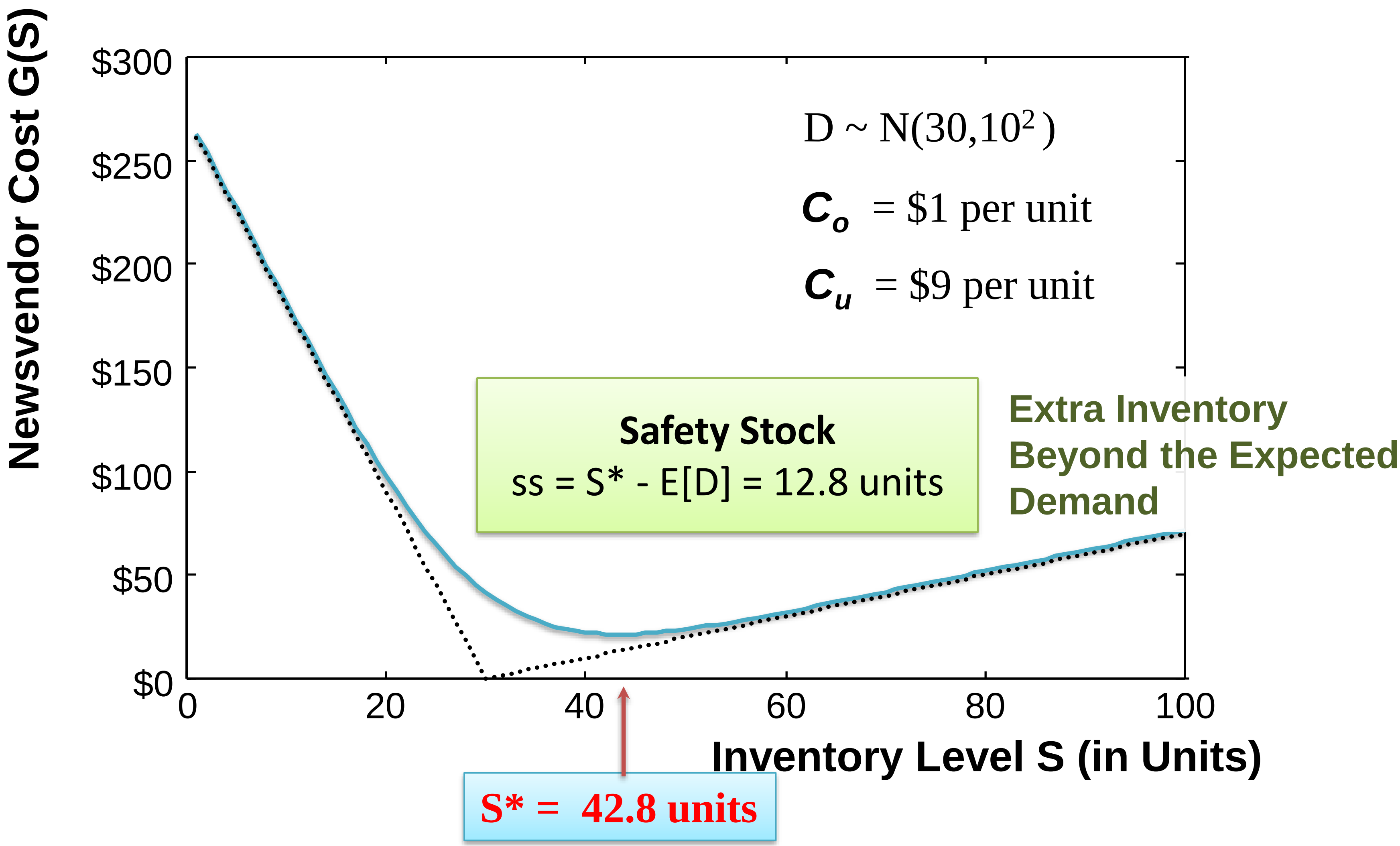
Unsold shirts can be sold off at $8 in the summer of 2021.

How many shirts should the HKU bookstore buy for the 2020-2021 academic year?

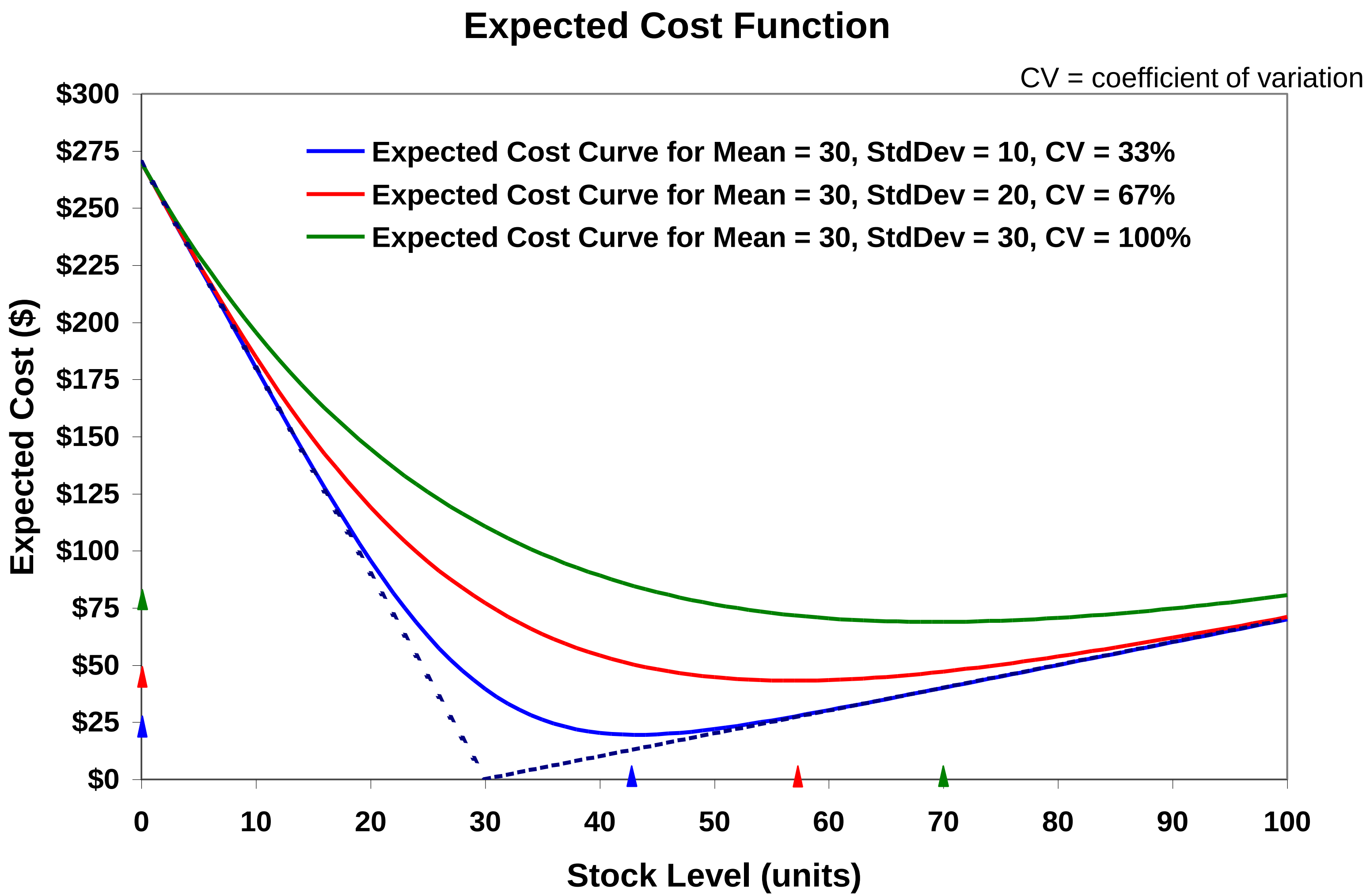
Mean demand	1000
STD of demand	200

C_o	
C_u	

Example 2: Newsvendor Model with Normal Demand



Impact of Demand Variability



Supply chain management

- Bullwhip effect
  - causes and ways to reduce the effect

- Supply chain coordination via contracts
  - Profit-sharing contract
  - Buyback contract

Revenue management

Managing demand:

- Price-based RM
- Capacity-based RM

Applying newsvendor logic to:

- Reserving capacity
- Overbooking

Traditional OM

- Production planning and scheduling
- Inventory management
- Warehouse & transportation

Modern OM

- Today OM studies many kinds of business processes.
- OM concerns both *manufacturing* and *service* industries.


organising
manufacture
economies of scale
lean production
organise
effective utilization of resources
delivery
functioning
delegation of an entire operation ex warehouse functionings
infrastructure
resources
organizing
admin , resources , finance , hr , delivery
solving
lean management
manufacturing,
customer service
effective
policies
function
organisation
day to day
database management
continuous improvement
customer
daily operations
organized
production
supply chain
coordination
customer satisfaction
tqm
company core
cost effective
functionality
controlling activities
results
managing the process
product
operate
leadership
functional
daily working
convenience
co-ordination
people
bottlenecks
business
order
sop
bank
opex
sales
continuity
foresight
discipline
facility layout
accuracy
processes
forecasting
plan
oee
kpi
execution
structure
best practices
manage
cost
ongoing
target
operations
control
company
review
efficiency, planning, strategy
organization
activities
decision making
business management
process
accommodation
time
network task
drive manufacturing readiness
big business
facilities
healthcare
drive
quality
organize
actions
chain
action
flow
hr
management
efficiency
communication
value
ahmad
decisions
effect output
integration
inventory
lean six sigma
inventory management
maintenance
growth
deliverables
profit
t
activity
accountability
planning
details
lean
customers
administration
cloud
manager
capacity
efficient
sale
productivity
finance
automation
logistics
effectiveness
man power
day to day operations
controlling
connectivity
issue
team
manufacturing
orchestration
operation
optimization
projects
manpower
fullfillment
factory
activity management
managing
overview
safety
metrics
implementation
day to day activities
service
organised
lean manufacturing
improvement
seamless
designing and controlling the production process and business operations
operational excellence
labour productivity
operation management
supply