KS SUPPLY CHAIN FUNDAMENTALS

09b Stochastic Inventory Management and Lean Operations

SS 2025

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Production and
Logistics Management

Learning goals

After this lecture you should ...

- ... know about the basic concepts of inventory management for perishable products.
- ... be able to explain the concept of lean operations.

Literature

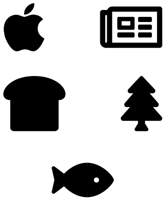
Stevenson, WJ: Operations Management. McGraw-Hill Education Ltd; latest edition - Chapters 12, 13, 14

C. Brabänder, Stochastisches Bestandsmanagement, essentials - Chapter 3 https://doi.org/10.1007/978-3-658-21470-8_3

Acknowledgements: icons are by fontawsome (latex) or by Pixelmeetup from www.flaticon.com

Perishable goods

- Fresh fruit
- Vegetables
- Sea fruits
- Flowers
- Newspapers
- Spare parts for specialized equipment
- ...

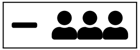


Goods can only be sold during a short period of time (single period) and lose (almost) all value afterwards → Newsvendor Problem

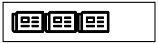
How much should be ordered?

Assumption: Demand at the time of ordering is unknown.

Consideration:

What happens if I order too few units? 

→ I incur a **stockout.** I could have sold more units.

What happens if I order too many units? 

→ I incur **leftover inventory.** Goods remain in inventory that may not be sold at full price.

Before ordering, I have to take into account the **excess cost** and the **shortage cost.**

Underage and overage cost

r	Revenue per unit
c	Cost per unit
s	Salvage value
p	penalty (for underage)

Overage cost:

$$c_o = c - s$$

Underage cost:

$$c_u = r - c \quad \text{or} \quad c_u = r - c + p$$

Balance point

Q	Quantity
$F(Q)$	Probability of the demand being less or equal to Q

Limit value consideration: When ordering one more unit than Q, then $F(Q)$ is the probability that this additional unit will be leftover inventory; ordering one unit less than Q, then the probability is $(1 - F(Q))$ that this unit will be in demand.
The optimal order quantity is reached when the costs of underage and the costs of overage for an additional unit are the same (*Balance Point*):

$$c_o \cdot F(Q) = c_u \cdot (1 - F(Q))$$

$$F(Q) = \frac{c_u}{c_u + c_o}$$

$$Q = F^{-1}(\frac{c_u}{c_u + c_o})$$

Critical ratio and service-level

Critical Ratio

$$c_r = \frac{c_u}{c_u + c_o}$$

The *critical ratio* c_r is interpreted as the optimal service level (*cycle service level*) α, that should be attained in a newsvendor situation (to maximize the expected profit).

The α service level gives the probability that no stockout occurs.

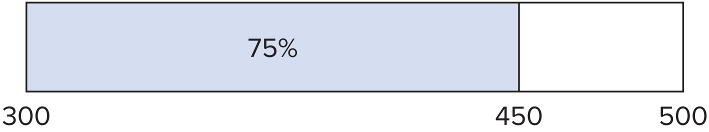
Example: uniformly distributed demand

Kepler's Bar gets fresh cider weekly. The demand fluctuates between 300 and 500 liters and is distributed uniformly. A liter is purchased at 20 cents and sold at 80 cents. Unsold cider has to be dumped at the end of the week. How many liters should be ordered?

$r = 80$, $c = 20$, $s = 0$

$c_u = r - c = 60$, $c_o = c = 20$

$c_r = c_u/(c_u + c_o) = 60/80 =$ 0.75



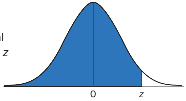
$Q^* = 300 + (500 - 300) \cdot 0.75 = 450$ liters

Example: normally distributed demand

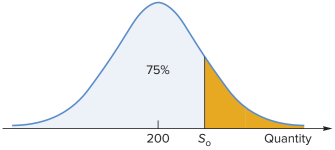
Kepler's bar also sells fresh cherry juice. The demand is distributed normally. The mean is 200 liters per week, the standard deviation is 10 liters per week. The costs of underage per liter are $c_u = 60$ cents and the costs of overage are $c_o = 20$ cents per liter. How many liters should be ordered?

$c_r = c_u/(c_u + c_o) = 60/80 =$ 0.75

Table B.2
Areas under the standardized normal curve, from $-\infty$ to $+z$



z	.00	.01	.02	.03	.04	.05	.06	.07	.08
.0	.5000	.5040	.5080	.5120	.5160	.5199	.5239	.5279	.5319
.1	.5398	.5438	.5478	.5517	.5557	.5596	.5636	.5675	.5714
.2	.5793	.5832	.5871	.5910	.5948	.5987	.6026	.6064	.6103
.3	.6179	.6217	.6255	.6293	.6331	.6368	.6406	.6443	.6480
.4	.6554	.6591	.6628	.6664	.6700	.6736	.6772	.6808	.6844
.5	.6915	.6950	.6985	.7019	.7054	.7088	.7123	.7157	.7190
.6	.7257	.7291	.7324	.7357	.7389	.7422	.7454	.7486	.7517
.7	.7580	.7611	.7642	.7673	.7703	.7734	.7764	.7794	.7823



$z = 0.67 \rightarrow Q^* = 200 + 0.67 \cdot 10 =$ 206.7 liters.

Example: discrete (empirical) demand distribution

Past data of the demand for spare parts of hydraulic presses are used to estimate the demand for spare parts of a new model. Costs of underage include the costs for downtime expenses and special ordering costs. These average 4200 euros per unit. Spare parts cost 800 euros each and unused parts have zero salvage value. Determine the optimal stocking level.

Spares used	0	1	2	3	≥ 4
Relative Frequency	0.2	0.4	0.3	0.1	0,0
Cumulative Frequency	0.2	0.6	0.9	1	

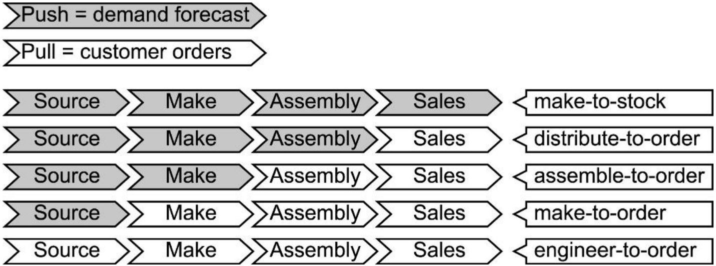
$c_u = 4200,\ c_o = 800$

$c_r = 4200/5000 = 0.84$

The cumulative frequency row indicates the percentage of time that demand did not exceed some amount. In order to achieve a service level of at least 84%, it will be necessary to stock two spares.

Excursus production strategy: push vs. pull

- **Pull process** triggerd by customer orders
- **Push process** based on demand forecasts.
- The border between push and pull is called **Order Penetration Point**.



Ivanov D., Tsipoulanidis A., Schönberger J. (2017). Global Supply Chain and Operations Management, Springer, 1st. Edition , Kapitel 6

Just in time (JIT) and lean operations

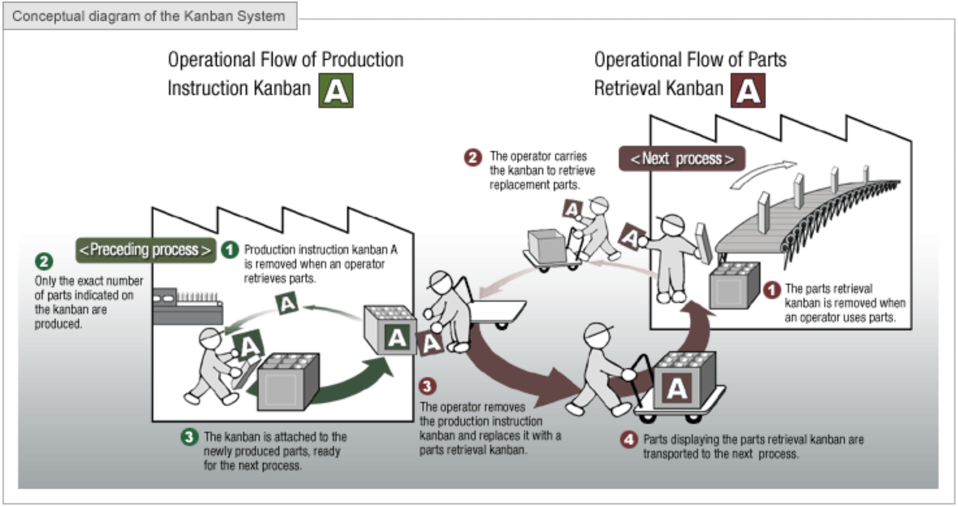
- Invented by Toyota.
- “Lean” describes the process to strive for excellence and continuous improvement. Workers are required to find mistakes and identify their causes.
- Lean Management follows 5 principles:
  - Identify customer value.
  - Focus on processes that create value.
  - Eliminate waste to create flow (Muda)
  - Produce only according to customer demand (e.g., Kanban)
  - Strive for perfection (Kaizen)

Kanban

- **Kanban** means “signal” or “card”
- A Kanban signal is used to highlight the need for the production of a (small) number of components.
- Restocking is triggered by actual material use.
- Simplification of the logistical process and material use.
- Use of circulating containers or boxes.
- Every container/box has a Kanban card. When emptying the container, the card is used „up-stream“ to initiate refilling.
- **Supermarket principle**: Material is taken from storage and the delivering department is authorized to refill the intentionally small storage. (Pull principle)

Video `https://youtu.be/F5vtCRFRAK0`

Kanban



Source: `http://logisticsglobal.blogspot.com/2011/10/kanban-system-parts-procurement-toyota.html`

JIT vs. MRP

JIT allows for lower stocking levels and improves relationships with resellers. However, a tight relationship with suppliers is required. This may render *multiple sourcing* more difficult.

JIT requires suppliers to deliver as fast as possible. Therefore, they need to be located close to the production center. Short setup times have to be possible and setups have to be cheap. MRP does not have these strict requirements.

There are studies showing that JIT only works well if the demand is fluctuating very little, the suppliers are highly reliable, etc. and that it works badly, if these circumstances are not given. MRP generally works well in all situations.

Summary

- Inventory management is very import along the supply chain and in production.
- Using the EOQ formula, the optimal order quantity for a single product with constant demand can be computed.
- Using the Silver-Meal heuristic, dynamic lot sizing problems can be solved. Dynamic means that multiple periods can be regarded and the demand may differ between periods.
- In single-period problems (perishable goods) with stochastic demand (uniform distribution, normal distribution, ...) the Newsvendor (or Newsboy) problem is solved.
- Lean Management/JIT has significant upsides as well as downsides.