Inventory Management, Planning and Control

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Agenda

TOPICS OF TODAY:

- EOQ and other inventory management concepts
- Inventory control systems and approaches
- ABC/XYZ Analysis
- Supply chain inventory management

READINGS:

Textbook 4th ed. Chapter 10

14. Abernathy, F. H., Dunlop, J. T., Hammond, J. H. and Weil, D. (2000): Control your inventory. *Harvard Business Review*, Vol.78, No.6, pp. 169-176.

15. Lee, H. and Billington, C. (1992): Managing Supply Chain Inventory: Pitfalls and Opportunities, *Sloan Management Review,* Vol.33, No.3, pp. 65-73.

Defining Inventory

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Inventory is another name for materials and is any material that a firm holds to satisfy customer demand

(and these customers may be internal and / or external to the firm)

A rather messy example…

Source: https://en.wikipedia.org/wiki/Die_Ludolfs_%E2%80%93_4_Br%C3%BCder_auf%27m_Schrottplatz

And Inventory is Everywhere!

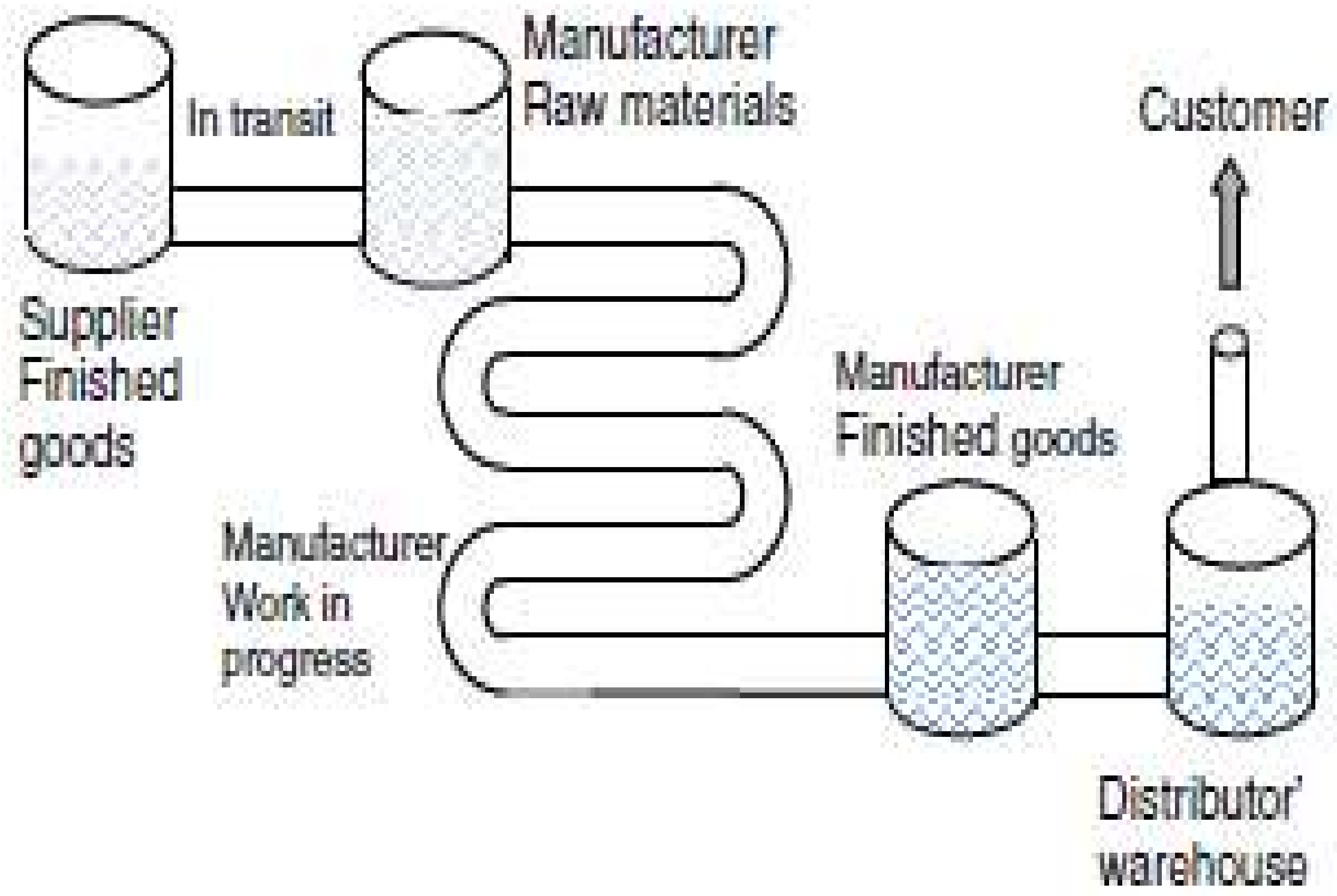

Figure 10.1 Supply chain pipeline

Discussion

**Why do we
need inventories?**

Why do we need inventory?

Table 10.1 Reasons for holding inventory

Buffer against uncertainty	Economic trade-offs
Maintain customer service levels for volatile demand	Production batch size
Hedge against price and exchange rate fluctuations	Transportation batch size
Protect against delivery lead-time variability	Transportation mode
Buffer against unreliable supply sources	Order quantity size
Buffer against seasonal demand and supply	Order frequency duration
Maintain supply of scarce supply	Bulk purchase savings
Provide cover for emergencies	Supply price fluctuations

Inventory Management

Purpose of Inventory Management

- Development of relevant inventory strategies.
- Achieving high inventory performance.
- Reduction of inventory and related cost as much as possible while still maintaining responsiveness, high customer satisfaction and general operational capabilities.

Key Decisions

- Size of the inventory – and time of stock keeping
- When reordering, what triggers the decision
- How much to order or reorder
- Where to locate how much inventory in the supply chain

Inventory Build-up and Depletion

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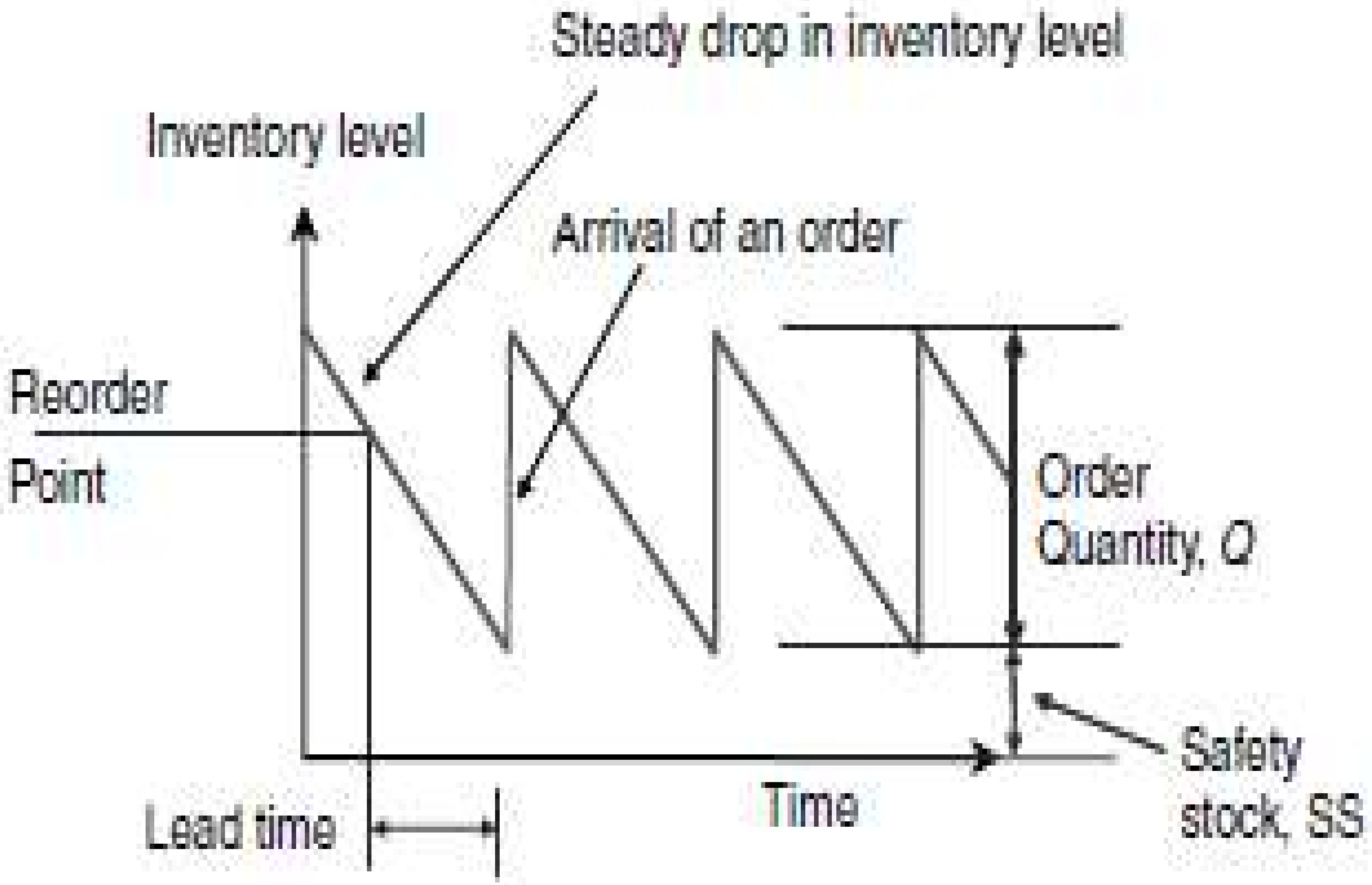
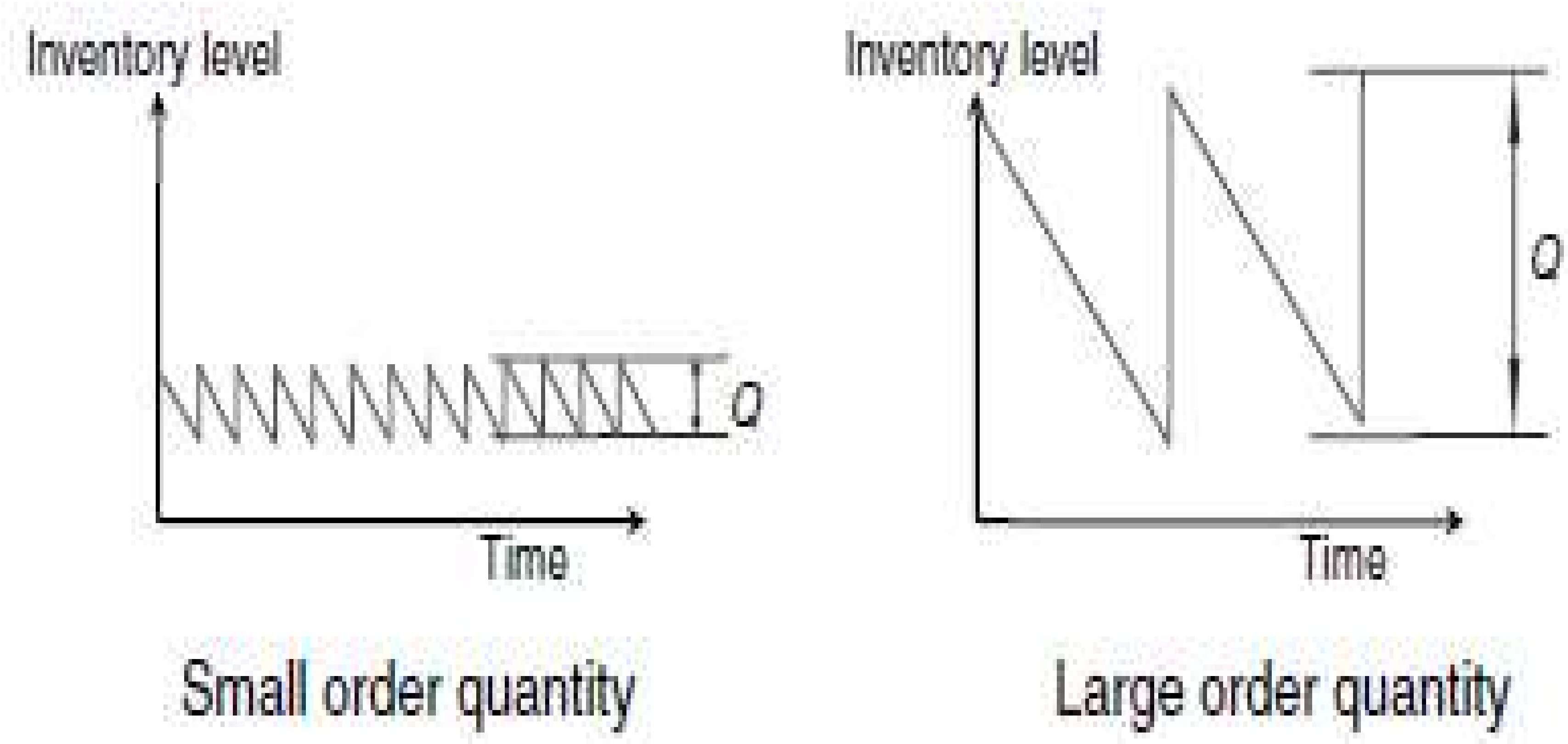
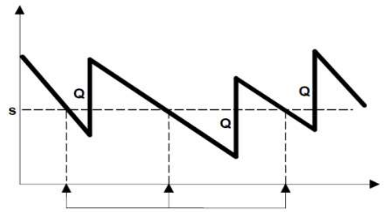
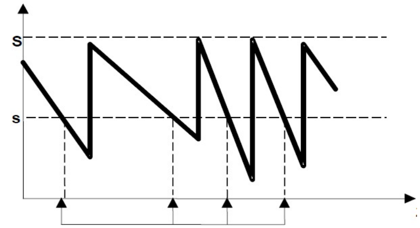
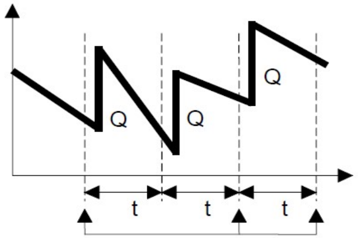
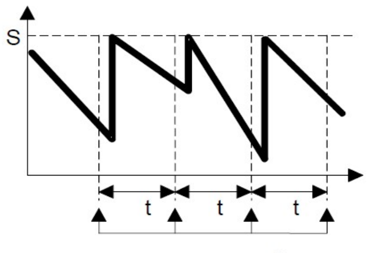


Small versus Large
Order Quantities / Frequencies



Reordering strategies

When to order how much?

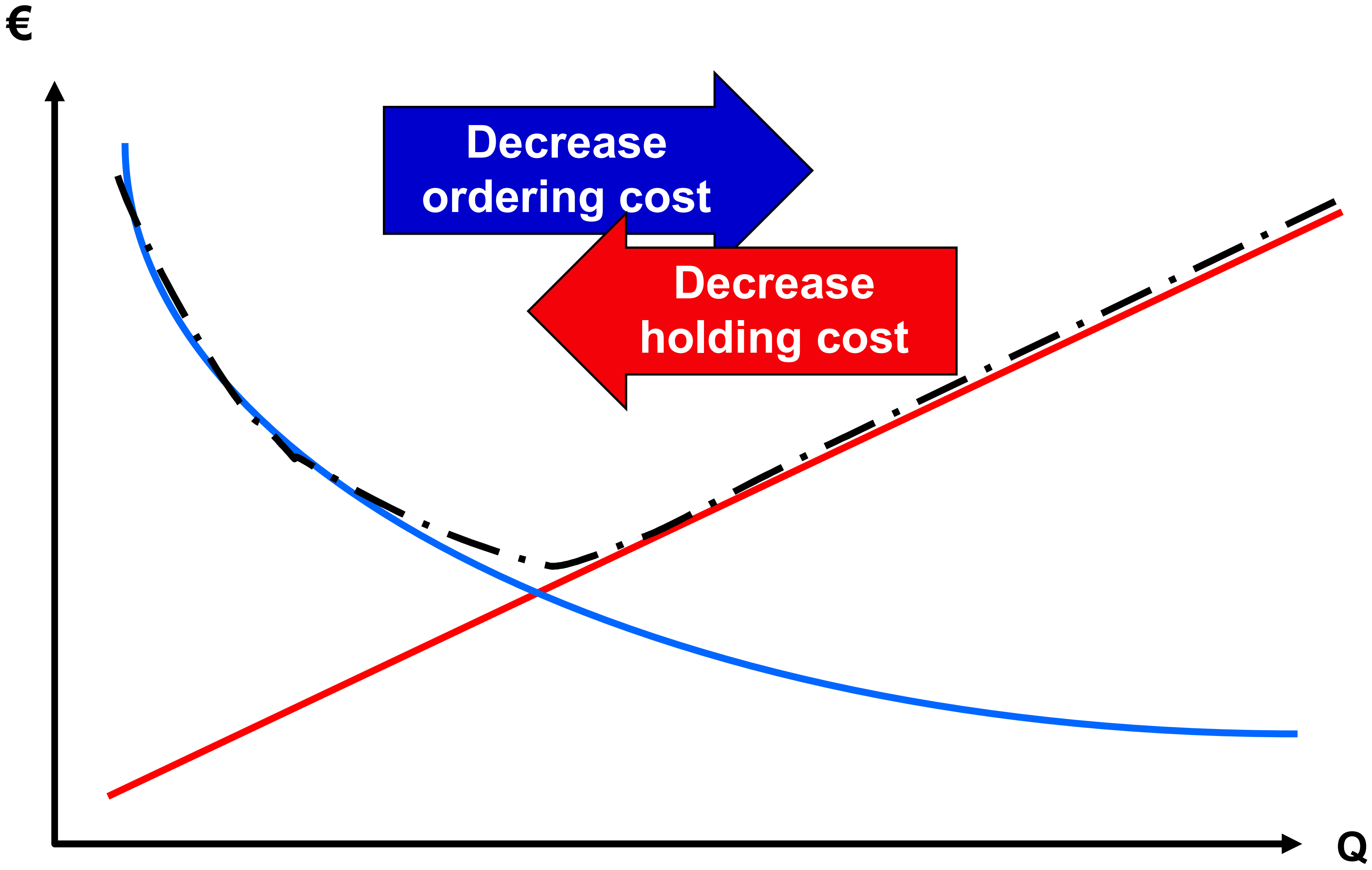
		Order-Quantities	
		Fixed Quantity **Q**	Always fillup to **S**
Time of Ordering	At defined level of inventory **s**		
	After defined cycle time **t**		

Reordering strategy rules

When to order how much?

		Order-Quantities	
		Fixed Quantity **Q**	Always fillup to **S**
Time of Ordering	At defined level of inventory **s**	(s,Q) Rule	(s,S) Rule
	After defined cycle time **t**	(t,Q) Rule	(t,S) Rule

How much to order?



The Economic Order Quantity (EOQ) Model

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Inventory costs can be classified in

- Purchase costs (price to be paid when buying)
- Order processing costs (costs of procuring the inventory)
- Inventory holding costs (warehousing etc.)

Notation in the following:

D: Annual use of a particular item, in number of items p.a.
S: Order-processing cost, in \$/order
p: Price per item, in \$/unit
H: Holding cost per unit per year, in \$/unit/year
Q: Number of items ordered in one purchase order, in units
T: Time periods between purchase orders in fraction of p.a.
SS: Safety Stock, in units
L: Lead time, in fraction of a year
I: Current inventory on hand, units
TAC: Total annual cost

Derivation of EOQ Formula (1/2)

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Assumptions

- ***Order processing cost*** *are equivalent to setup cost as the total sum of labor and material cost to produce a product,*
- *Large lots reduce setup costs, but small lots reduce inventory.*
- ***Purchase costs*** *remain stable throughout the year and no discount on bulk purchases is granted.*

Purchase costs = $p \times D$

Average inventory level = $SS + Q/2$

Annual holding costs = $(SS + Q/2)\, H$

Number of orders per year = D/Q

Annual order processing costs = $(D/Q)\, S$

Derivation of EOQ Formula (2/2)

Total annual costs (TAC)

$$TAC = p \times D + (SS + Q/2)\, H + (D/Q)\, S$$

Then first-order differentiation:

$$\frac{\partial TAC}{\partial Q} = 0$$

$$\frac{\partial (p \times D + (SS + Q/2)\, H + (D/Q)\, S}{\partial Q} = 0$$

$$H/2 - D \times S / Q^2 = 0$$

and finally $\boldsymbol{Q = \sqrt{2DS/H}}$ **=> *EOQ Formula***

And second-order differentiation is positive:

$$\frac{\partial^2 TAC}{\partial^2 Q} = \frac{\partial H/2 - D \times S / Q^2}{\partial Q} = -(-2)\frac{D \times S}{Q^3} > 0$$

Example

?!

Pam runs a mail-order business for gym equipment. Annual demand for the TricoFlexers is 16,000. The annual holding cost per unit is \$2.50 and the cost to place an order is \$50. What is the economic order quantity?

Using the same holding and ordering costs as above, suppose demand for TricoFlexers doubles to 32,000. Does the EOQ also double? Explain what happens.

$$Q^* = \sqrt{\frac{2DS}{H}}$$

How much to order? What is the EOQ?

H = \$2.50

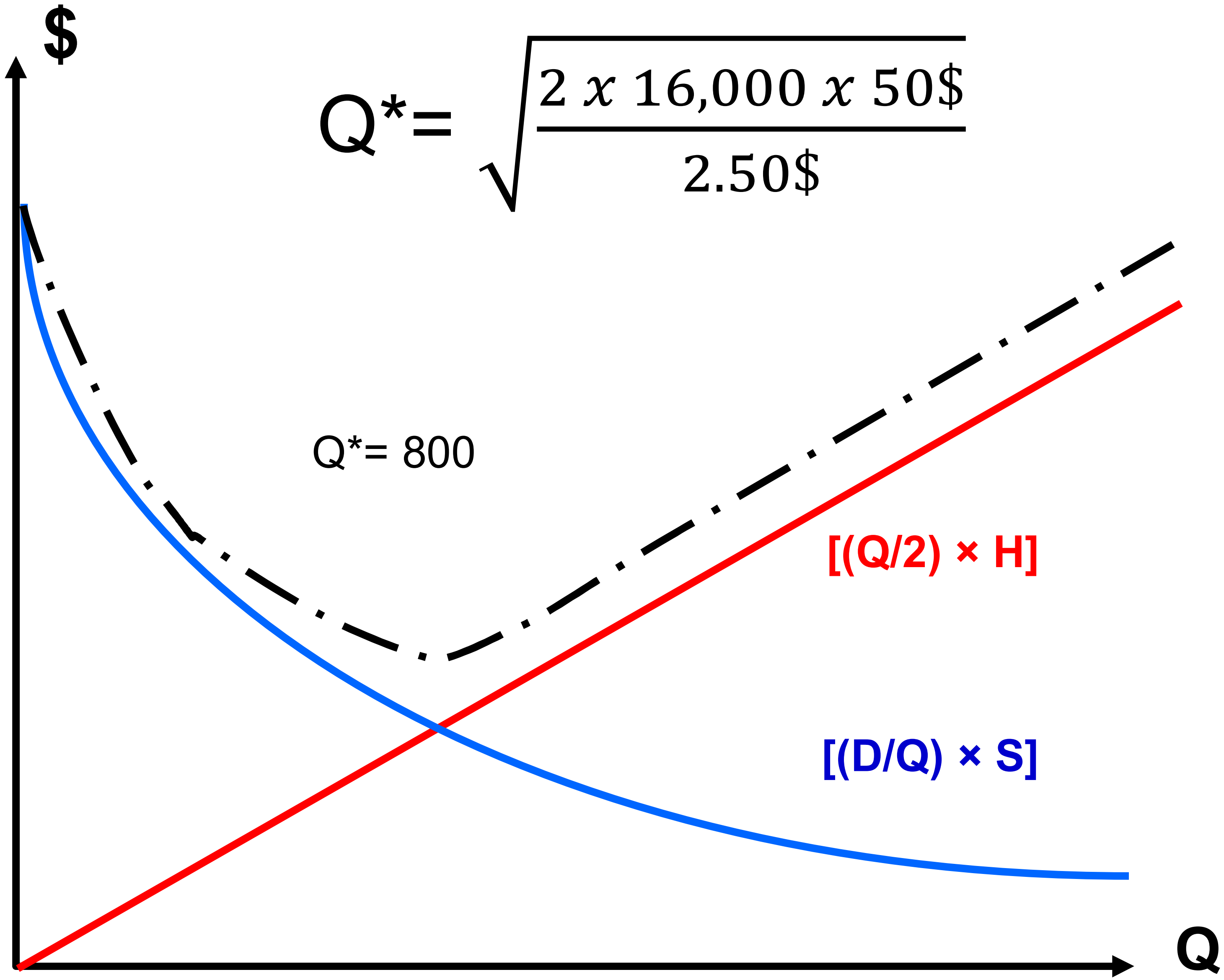
S = \$50

D = 16,000

Q*= 800

D = 32,000

Q* = 1131.37



Periodic Inventory Control System

In the periodic inventory control system: orders are reviewed **periodically** after the passage of a fixed time period (*T*):

$T = EOQ / D$

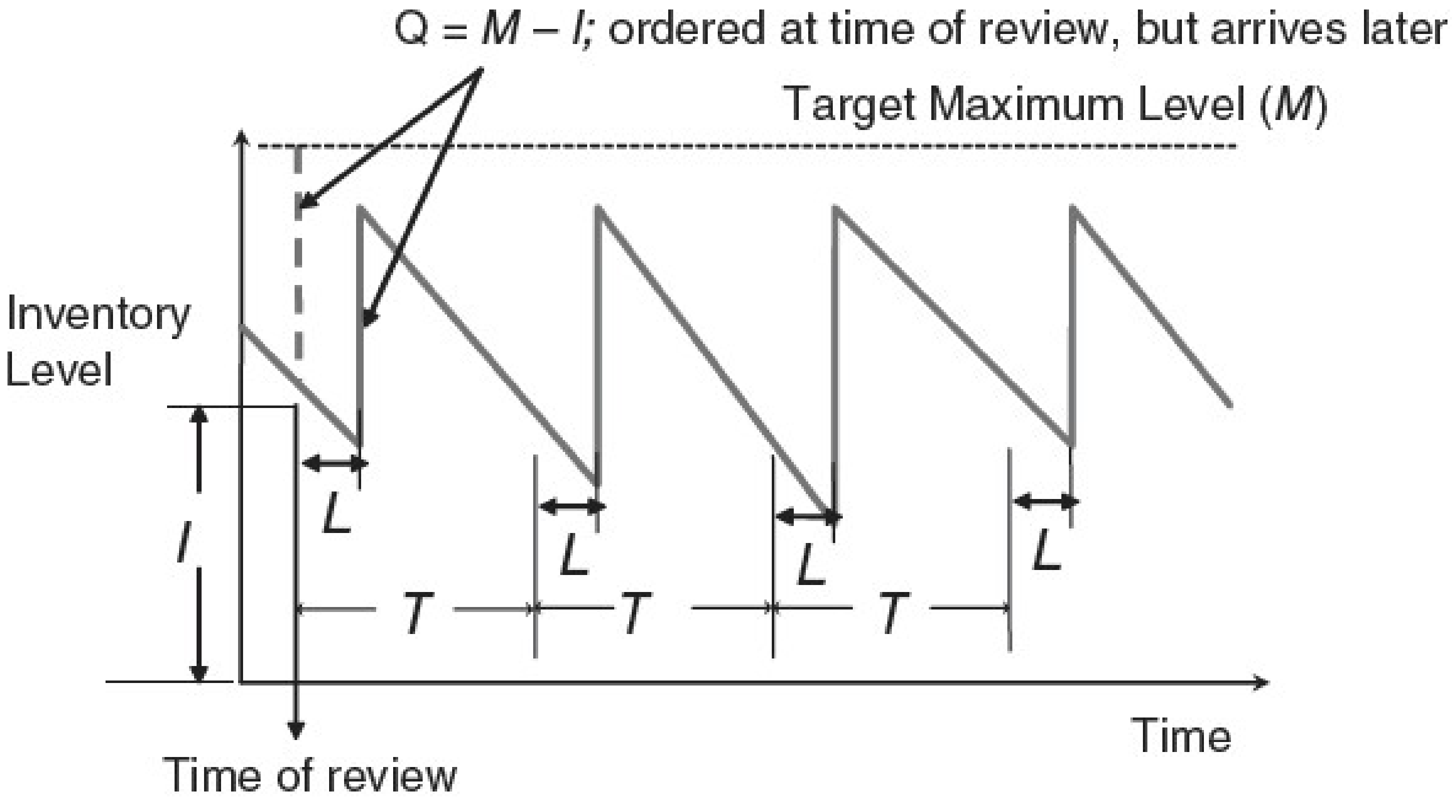


Figure 9.5 Periodic system

Reorder Point Inventory Control

In a reorder point inventory control system, inventory levels are **continuously** monitored, and orders are issued when the inventory is depleted to a predetermined level, called the reorder point (*ROP*)

$ROP = D \times L + SS$

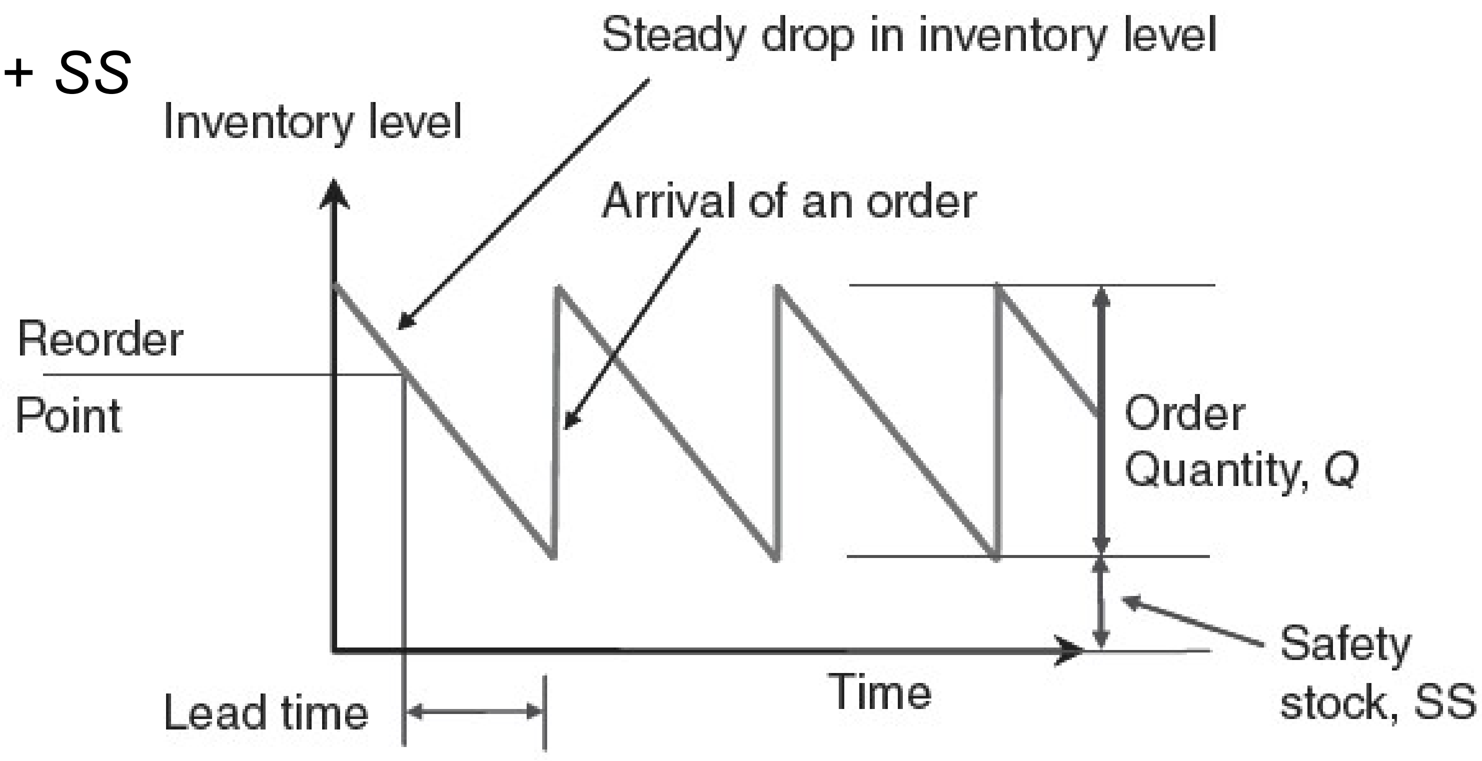
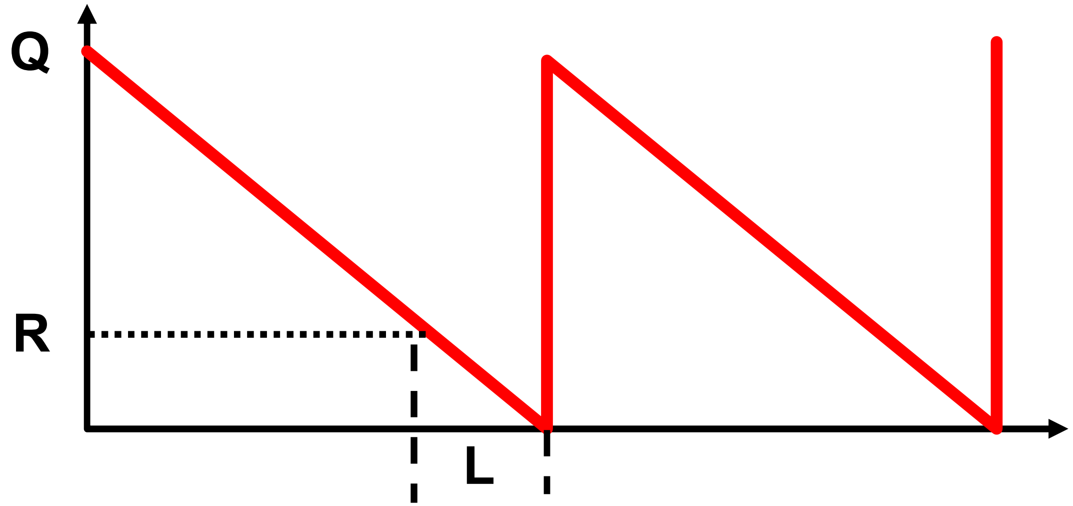


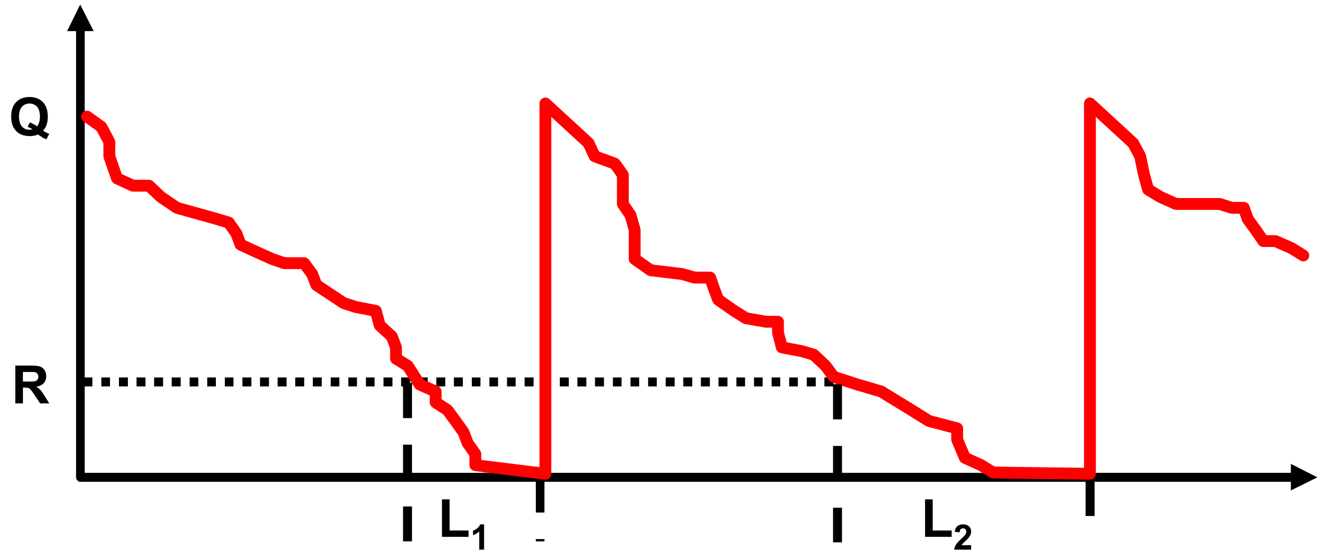
Figure 9.2 Inventory build-up and depletion

Now Environment is less predictable…

When both lead time and demand are constant, you know <u>exactly</u> when your reorder point is ...



But what happens when either demand or lead time varies?

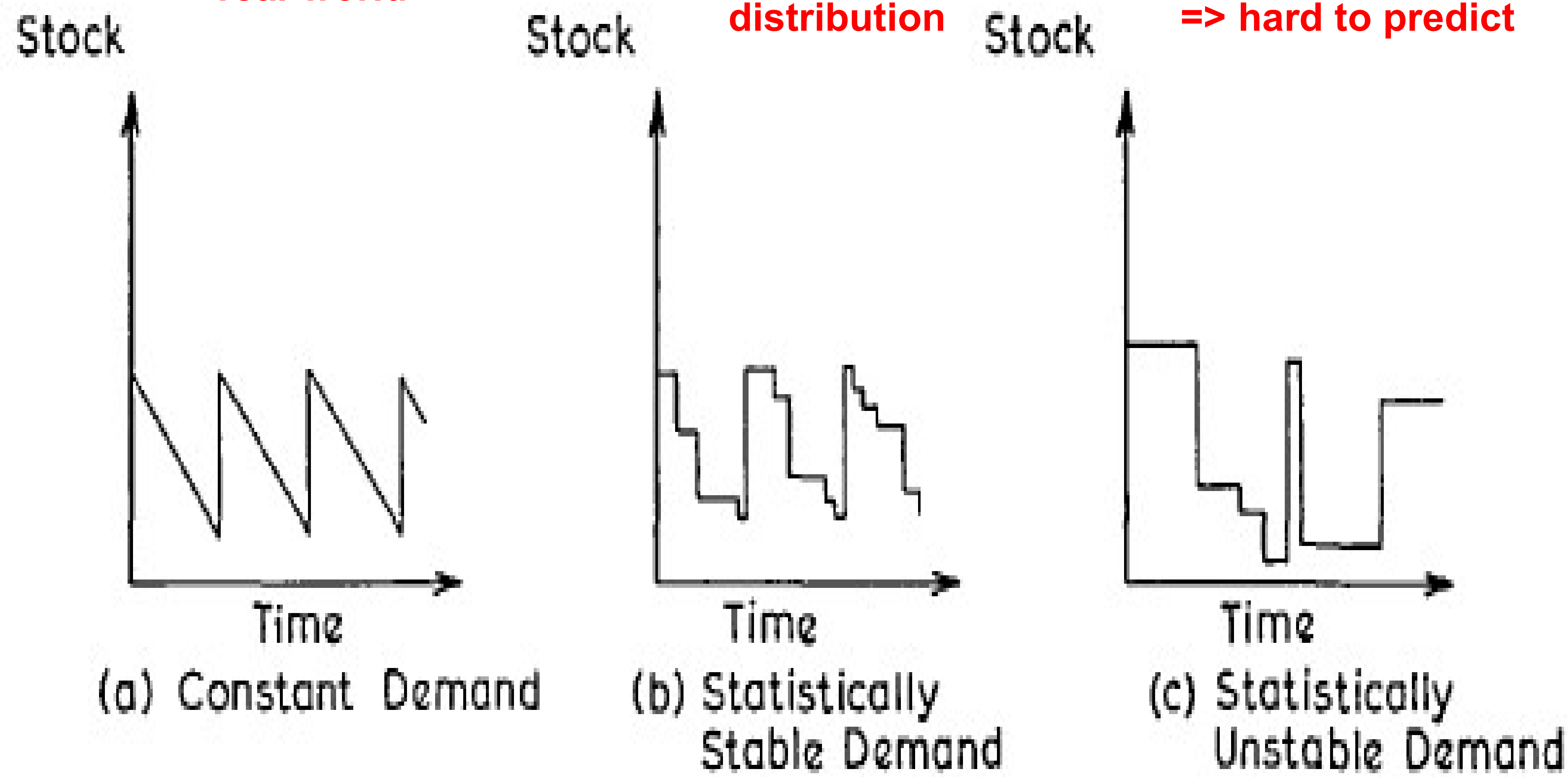


Different Type of Demands

Quite rare in real-world

Average demand stable => normal distribution

No direct analysis, short terms forecasting => hard to predict



Reorder Point Calculation including Safety Stock

$$ROP = DxL + SS = DxL + z\sqrt{\bar{L}\sigma_d^2 + \bar{d}^2\sigma_L^2}$$

$where:$

$\bar{d} = average\ demand\ per\ time\ period$

$\bar{L} = average\ lead\ time$

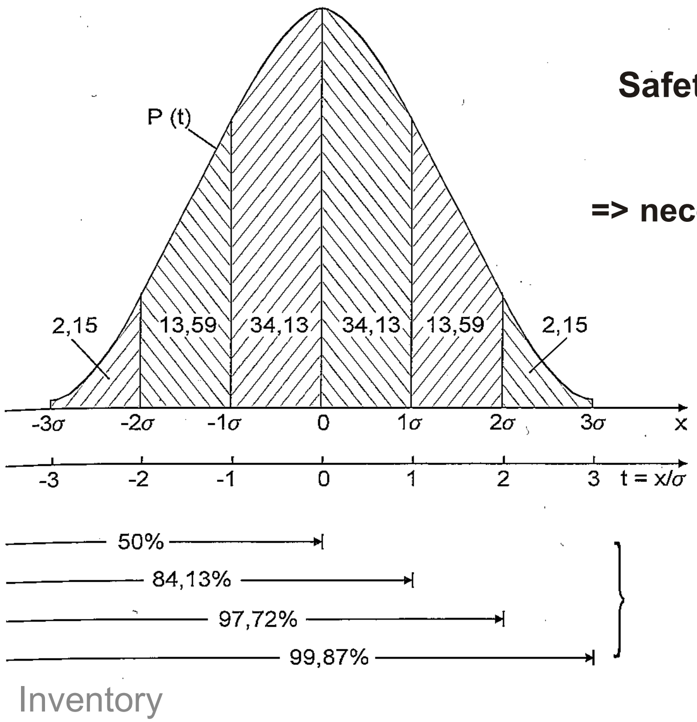
$\sigma_d^2 = \text{variance}\ of\ demand\ during\ time\ period$

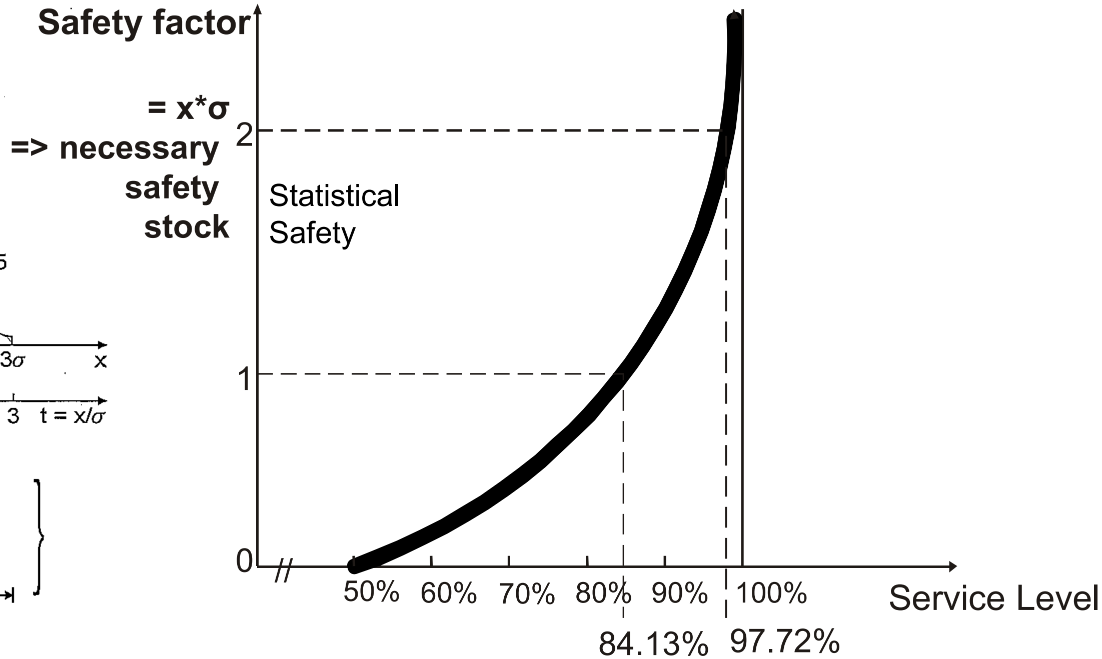
$\sigma_L^2 = \text{variance}\ of\ lead\ time$

$z = number\ of\ \text{standard}\ deviations\ above\ the$
$average\ demand\ during\ lead\ time$

Determing Size of the Safety stock

Relationship of service level to safety stock level
Example for normal distribution of demand





Example:

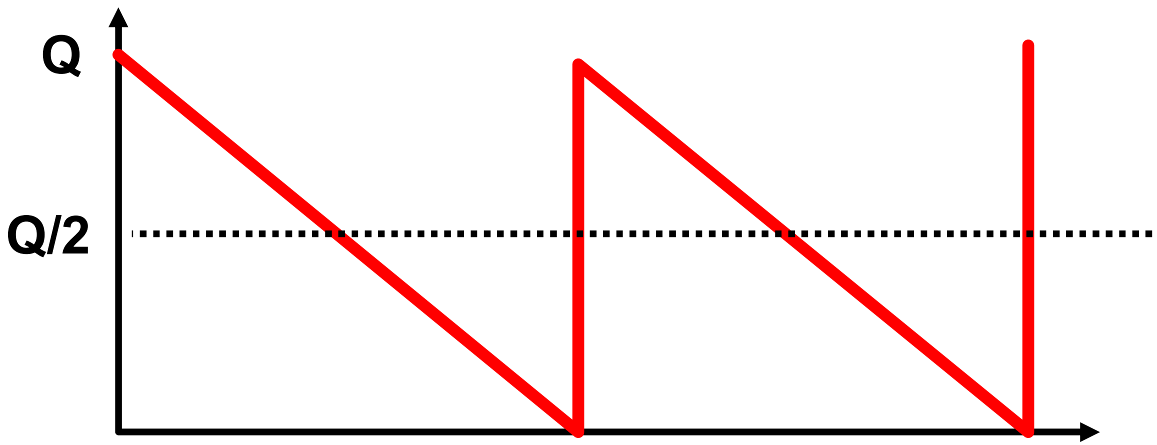
When average demand $\bar{d}$ = 100.000 units with standard deviation σ_d = 20,
average lead time $\bar{L}$ = 1 period, and this is stable (ergo σ_L =0)
Then we need 2σ = 40,000 Units Safety Stock SS
for a Service Level of 97,72 % ….

And Finally…
Inventory Turnover

- Used to measure a firm’s performance in inventory management.
- It compares annual sales with the amount of average inventory held throughout the year or

$$\frac{\text{Cost of all goods (COGS) sold in a year}}{\text{Value of average inventory held throughout a year}}$$

- The higher the turnover, the lower the firm’s inventory costs
- Most firm achieve a turnover of about 10 while well-performing firms can achieve a turnover of 50 or more!



Now another Topic…

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Hands on:

You got from your boss the attached table with information.

He says:
„think about improving our inventory situation"

What could you do, where would you start?

Article #	Consumption	Price (in Euro)
A 5.831	300	14,-
B 4.223	200	4,-
D I.798	500	12,-
E 6.185	800	6,-
L 2.741	1,500	2,-
L 3.311	1,000	2,80
M 7.439	1,000	-,20
M 7.820	2,000	-,80
N 2.784	200	23,-
P I .437	50	80,-
R 6.874	50	200,-
R 8.413	100	34,-
T 2.880	200	40,-
V 2.828	2,000	-,45
X 8.427	2,500	-,60

ABC Analysis, Pareto Principle or 80/20 Rule

Idea:

- ABC analysis separates out the most important items so that more attention can be focused on those items.
- It is based on the principle that out of the myriad of items an inventory manager needs to handle, there are only a few that account for most of the inventory expenses.

Checklist:

1. Calculation of the total consumption value of each material per period (quantity multiplied by the cost price)
2. Calculate percentage with respect to the total number of consumed goods
3. Calculate percentage with respect to the total consumption value of all goods
4. Rank material types in descending order with respect to the total consumption value
5. Cumulate these percentages with respect to the total number of consumed goods
6. Cumulate the percentage of the total consumption value of all goods
7. Classification of material types in A, B and C goods

ABC Analysis – Step 1-4

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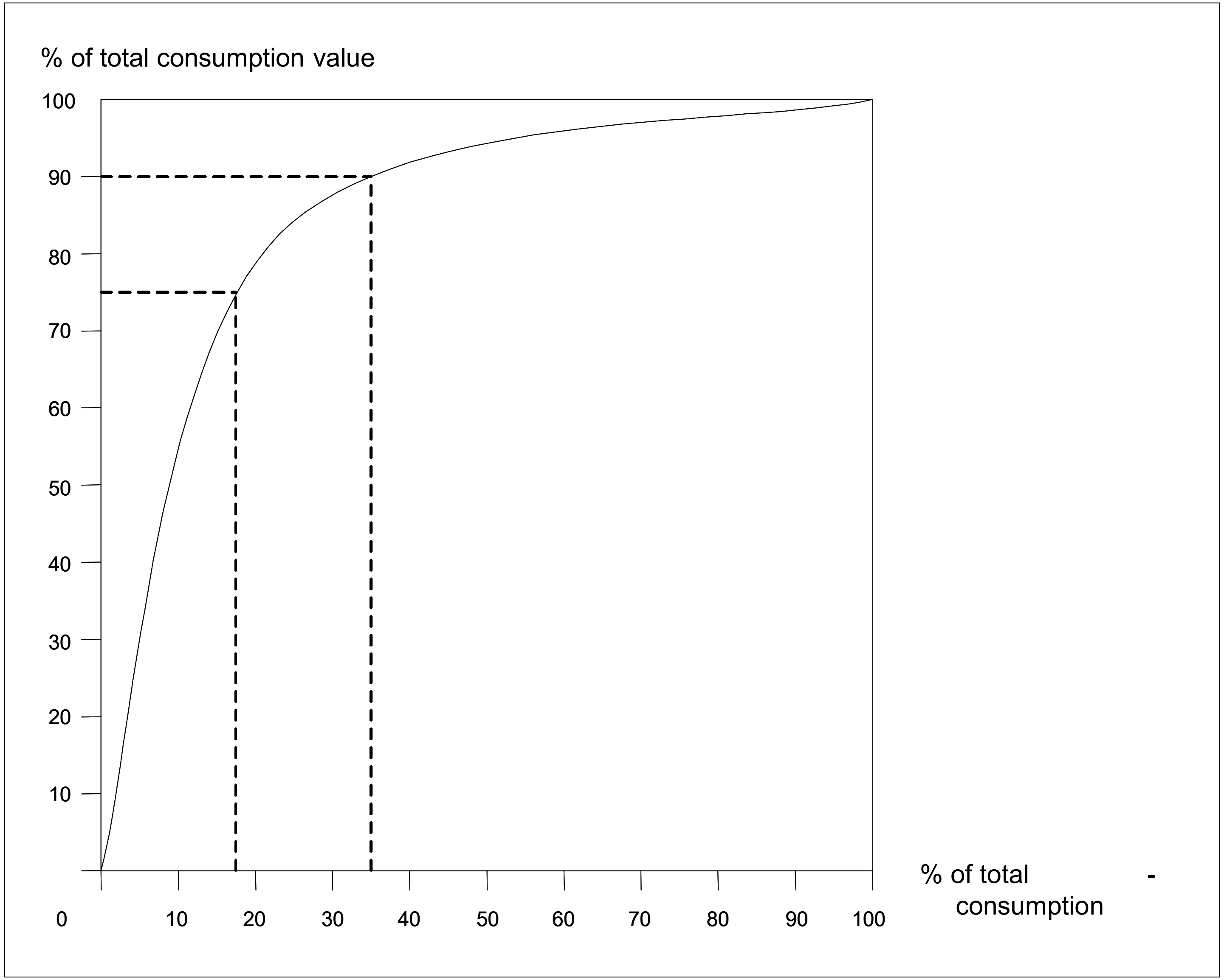
Article	Consumption (2) In units	Consumption in %	Price	Consumption value (1) in total units	Consumption value (3) in %	Rank (4)
A 5831	300,00	1,8	14,00 €	4.200,00	7,4	6
B 4223	200,00	1,2	4,00 €	800,00	1,4	15
D 1798	500,00	3,0	12,00 €	6.000,00	10,6	3
E 6185	800,00	4,9	6,00 €	4.800,00	8,5	4
L 2741	1.500,00	9,1	2,00 €	3.000,00	5,3	9
L 3311	1.000,00	6,1	2,80 €	2.800,00	4,9	10
M 7439	5.000,00	30,5	0,20 €	1.000,00	1,8	13
M 7820	2.000,00	12,2	0,80 €	1.600,00	2,8	11
N 2784	200,00	1,2	23,00 €	4.600,00	8,1	5
P 1437	50,00	0,3	80,00 €	4.000,00	7,1	7
R 6874	50,00	0,3	200,00 €	10.000,00	17,7	1
R 8413	100,00	0,6	34,00 €	3.400,00	6,0	8
T 2880	200,00	1,2	40,00 €	8.000,00	14,1	2
V 2828	2.000,00	12,2	0,45 €	900,00	1,6	14
X 8427	2.500,00	15,2	0,60 €	1.500,00	2,7	12
Total	16.400,00	100,0		56.600,00	100,0	

ABC Analysis – Step 5 - 7

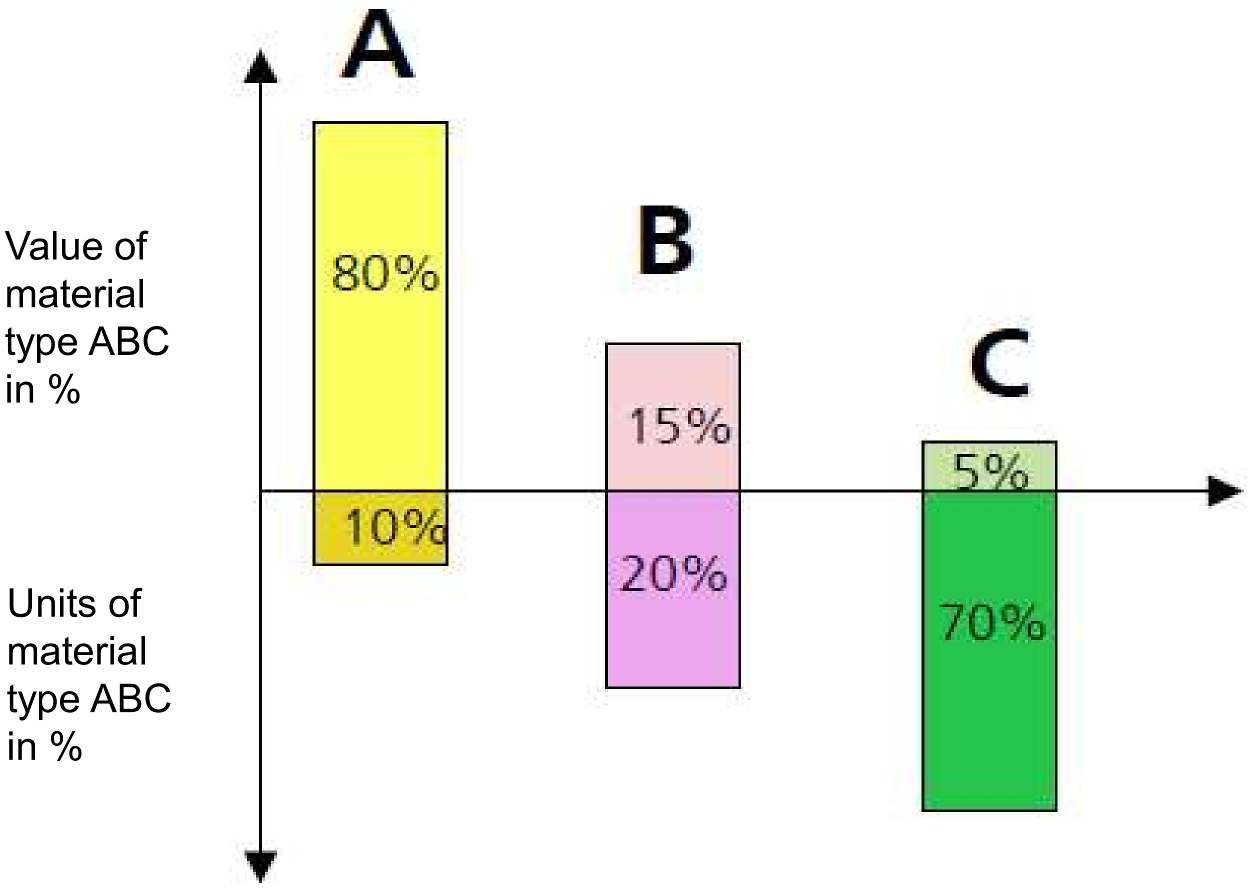
Rank	Article	Consumption in %	5 cumulated	Consumption per class in %	Value conumption in %	6 cumulated	Value consumption per class in %	7 Class
1	R 6874	0,3	0,3	12,8	17,7	17,7	73,5	A
2	T 2880	1,2	1,5		14,1	31,8		
3	D 1798	3,1	4,6		10,6	42,4		
4	E 6185	4,9	9,5		8,5	50,9		
5	N 2784	1,2	10,7		8,1	59		
6	A 5831	1,8	12,5		7,4	66,4		
7	P 1437	0,3	12,8		7,1	73,5		
8	R 8413	0,6	13,4	15,9	6	79,5	16,2	B
9	L 2741	9,2	22,6		5,3	84,8		
10	L 3311	6,1	28,7		4,9	89,7		
11	M 7820	12,2	40,9	71,3	2,8	92,5	10,3	C
12	X 8427	15,2	56,1		2,7	95,2		
13	M 7439	30,5	86,6		1,8	97		
14	V 2828	12,2	98,8		1,6	98,6		
15	B 4223	1,2	100		1,4	100		

Lorenz Curve: ABC-Analysis Reflects Pareto Principle or 80/20 Rule

7



Example:
ABC-Classification of Materials



SO WHAT?

XYZ Analysis along Inventory flow types

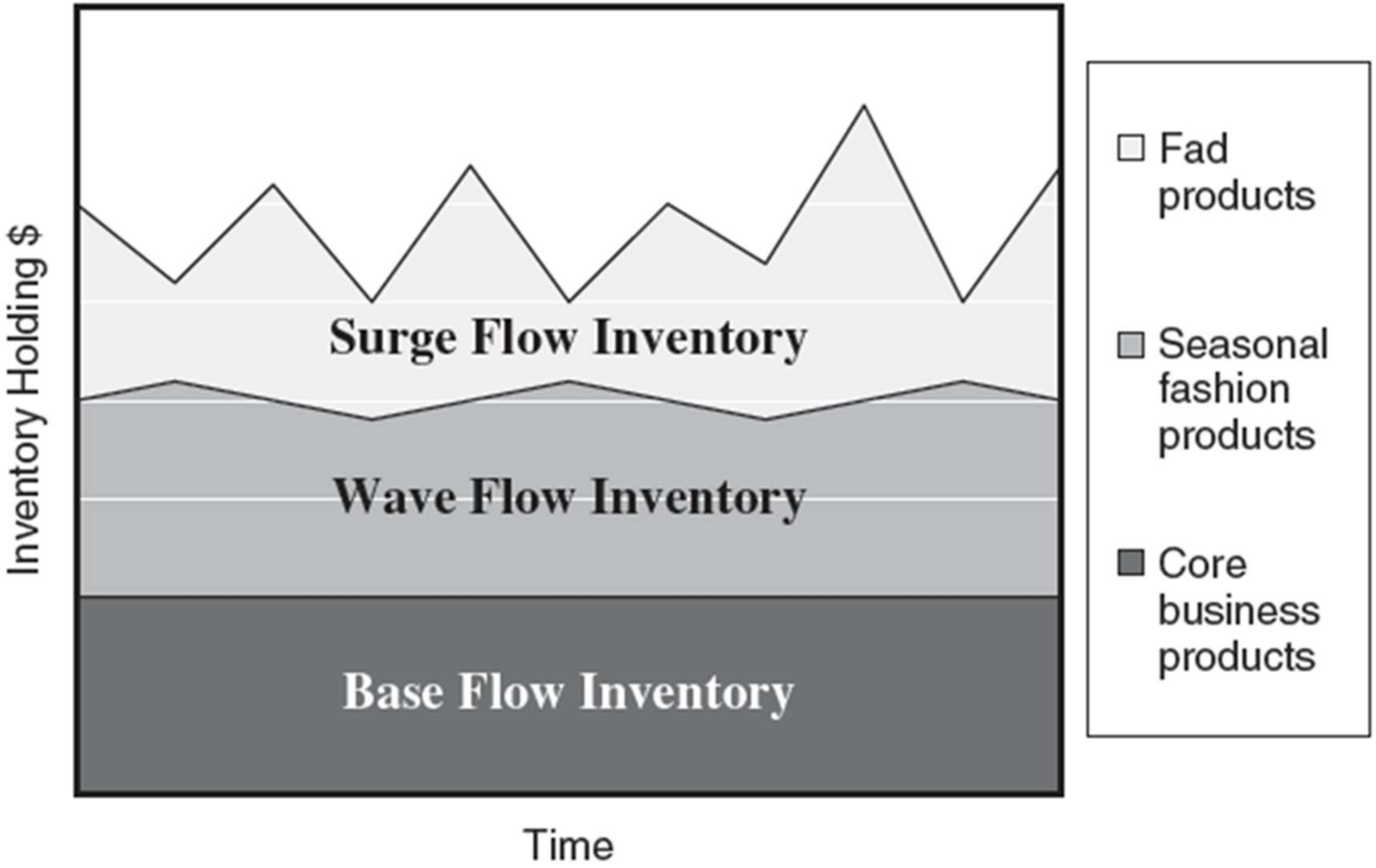


Figure 9.10 Inventory flow types. (Source: Gattorna & Walters, 1996)

Inventory flow types and stockholding policies

Table 9.3 Stockholding policies for alternative inventory flow types

Type	Characteristics	Stockholding policy
Base flow	Predictable high flow rates	Minimum stocks. Direct deliveries from suppliers
Wave flow	Slow moving flow rates. High criticality. Perishable. Peaks are relatively predictable	Minimise stockholding, building them during peak demand period. Direct delivery from supplier where possible
Surge flow (1)	High criticality. Low value. Long lead time. Small physical size	Hold high level of stock thereby allowing safety stock delivery lead time and demand fluctuations
Surge flow (2)	Low criticality. High value. Bulky physical characteristics. Peaks are relatively predictable	Minimise stockholding, building them only during peak demand period. Direct delivery from supplier where possible

Combined ABC-XYZ Analysis

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	X Easy to predict	Y Predictability on average	Z Difficult to predict
A High volume or high value share	Stable and constant demand	Fluctuating demand	Irregular demand
B Volume or value share on average	Stable and constant demand	Fluctuating demand	Irregular demand
C Low volume or high value share	Stable and constant demand	Fluctuating demand	Irregular demand

- **ABC/XYZ analysis** serves a better clas-sification of available stocks and/or goods needed
- With **ABC analysis** the individual articles are judged according to their portion (high value, middle value, small value) of the enterprise conversion.
- With **XYZ analysis** sales of durable articles, season articles and special offers can be prognosticated.

Inventory Reduction Strategies

Inventory centralization:
variation of total demand is reduced
=> inventory reduction according to **square root rule**,
lower safety stock levels needed at central location

Delayed product differentiation:
Reducing variation by combining demand at different points is the case of a manufacturer making multiple products
=> postponement / delayed product differentiation

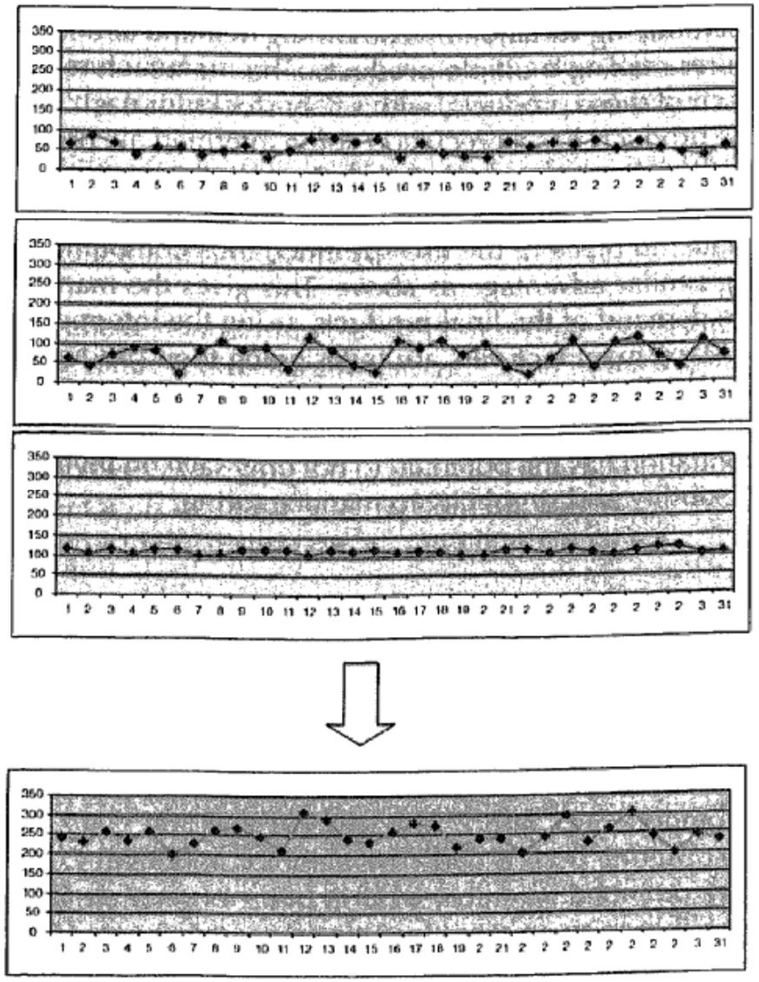
Part commonality:
Attempts simply to reduce the number of different parts in a product range wherever possible
=> again postponement / delayed product differentiation

Transit inventory reduction
=> reducing lead times for lower transit inventory costs

Inventory Centralization

The effect of inventory reduction centralisation is also called ‚**Square-Root-Rule**‘:
Safety stock level needed is proportional to the square root of the number of locations.

In the example here:
$\sqrt{1}/\sqrt{3}$ =0.58 or approx. 42% less than in the initial case of three distribution centres



Demand at distribution centre A: Safety stock = 35

Demand at distribution centre B: Safety stock = 60

Demand at distribution centre C: Safety stock = 12

Demand at central location: Safety stock = 62

Pitfalls in Managing Supply Chain Inventory (1/3)

Pitfalls related to information definition and supply chain management

1. No supply chain metrics	• Independent and disconnected individual sites • Incomplete metrics • Performance measures not tracked • No attention to measures tracked
2. Inadequate definition of customer service	• Inadequacy of line-item fill rate measure • No measures for response times • No measures for lateness • No measures for backorder profile
3. Inaccurate delivery status data	• Delays in providing delivery information • Inaccurate delivery information
4. Inefficient information systems	• Inadequate linkage among databases at different sites • Proliferation of operating systems for the same function at different sites • Delays and inaccuracies of data transfer

Source: Lee and Billington (1992)

Pitfalls in Managing Supply Chain Inventory (2/3)

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Pitfalls related to operational problems along the supply chain

5. Ignoring the impact of uncertainties	• No documentation or tracking of key sources of uncertainties • Partial information on sources of uncertainties
6. Simplistic inventory stocking policies	• Stocking policies independent of magnitudes of uncertainties • Static stocking policies • Generic and subjective stocking policies
7. Discrimination against internal customers	• No service measures of internal customers • Low priority for internal orders • Inappropriate incentive systems • Jockeying for priority among different internal divisions
8. Poor coordination	• No coordination among supplying divisions to complete an order • No system information among multiple supplying divisions • Independent shipment plans
9. Incomplete shipment methods analysis	• No consideration of inventory and response time effects

Source: Lee and Billington (1992)

Pitfalls in Managing Supply Chain Inventory (3/3)

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Pitfalls related to supply chain strategy and design

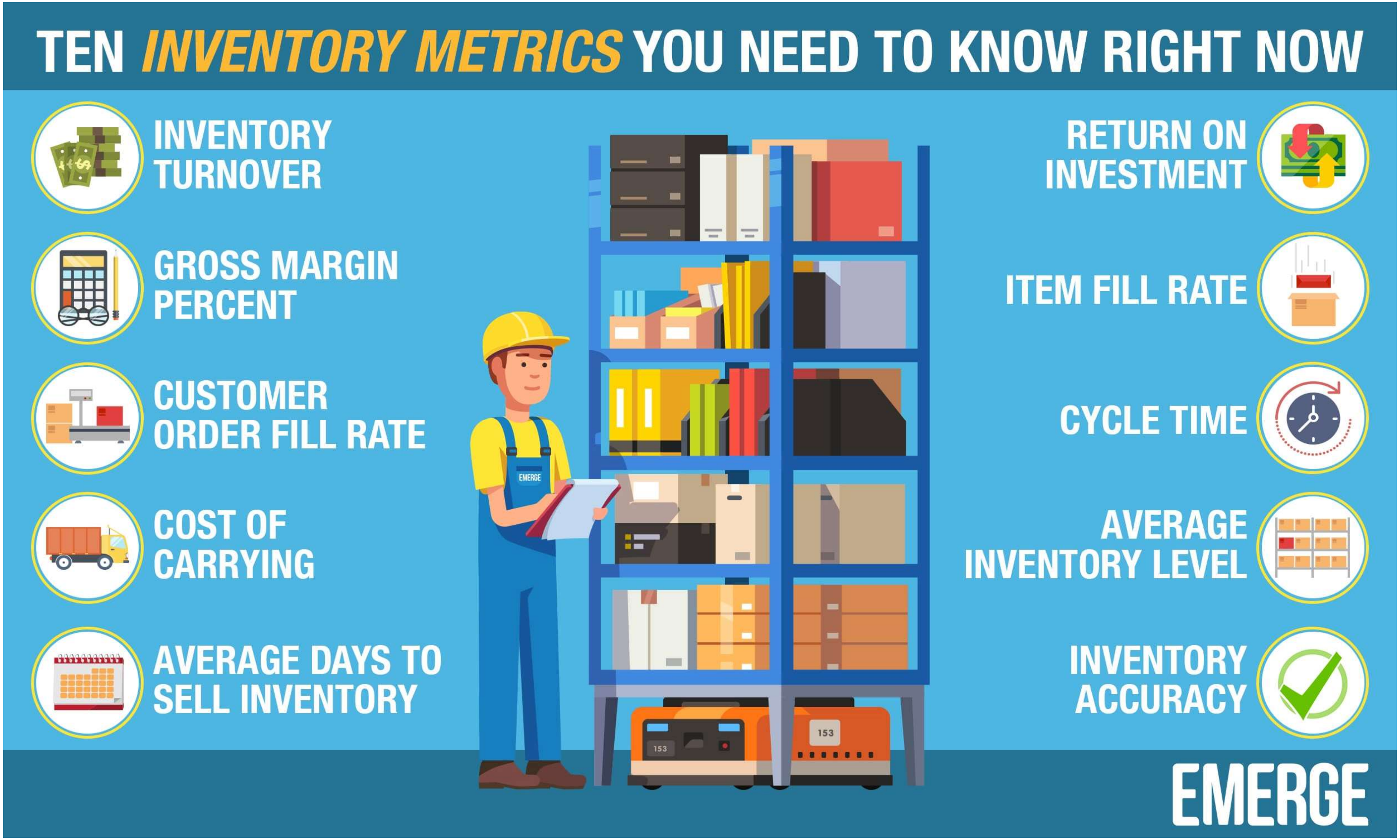
10. Incorrect assessment of inventory costs	• Omission of obsolescence and cost of rework • No quantitative basis for inventory holding cost assessments
11. Organizational barriers	• Independent performance measures and incentive systems at different sites • Barriers between manufacturing and distribution
12. Product-process design without supply chain consideration	• No consideration of manufacturing and distribution in product-process design • No consideration in design for customization and localization • Organizational barriers between design and the supply chain
13. Separation of supply chain design from operational decisions	• Chain decisions without consideration of inventory and response time efficiencies
14. Incomplete supply chain	• Focus on internal operations only • Inadequate understanding of operational environment and needs of immediate and ultimate customers

Source: Lee and Billington (1992)

Wrap-Up: Inventory Management…

Source: https://emergeapp.net/inventory-reports/inventory-management-techniques/

…and Control



Source: https://emergeapp.net/inventory-reports/10-inventory-metrics-for-smbs/