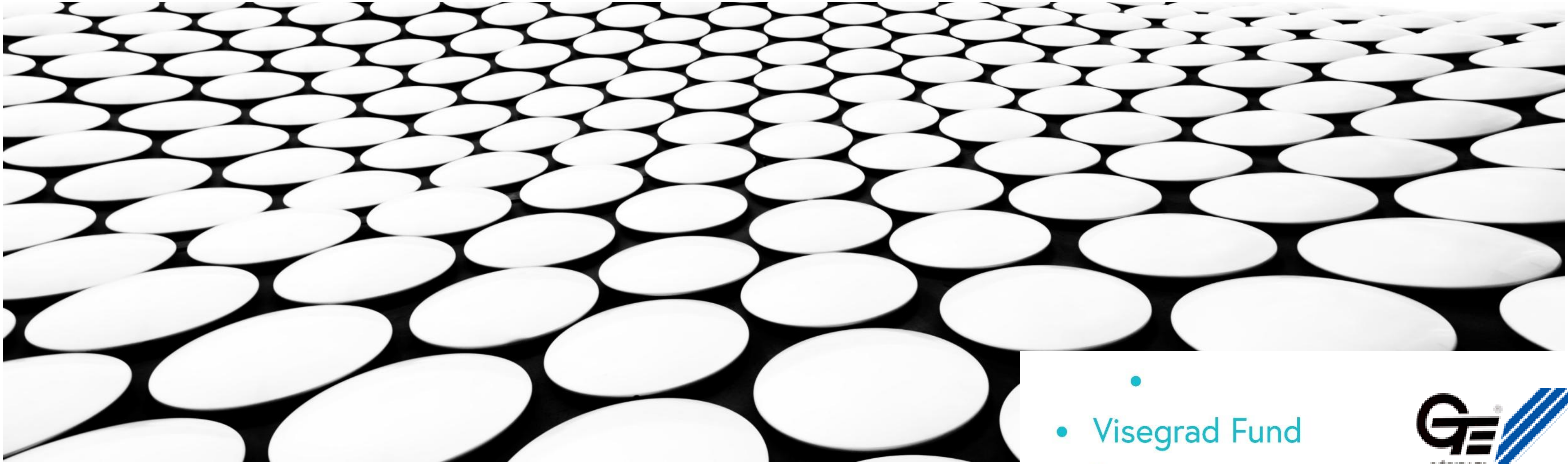
SCM relationships and inventory management impacts

The module presents the relationships between SCM and inventory management, highlighting the role of forecasting in reducing inventory risks and establishing optimal inventory levels.



Visegrad Fund

GÉPIPARI TUDOMÁNYOS EGYESÜLET

Visegrad Grant No. 22520049

INTERPRETATION OF THE SUPPLY CHAIN

Planned, forward-looking operation

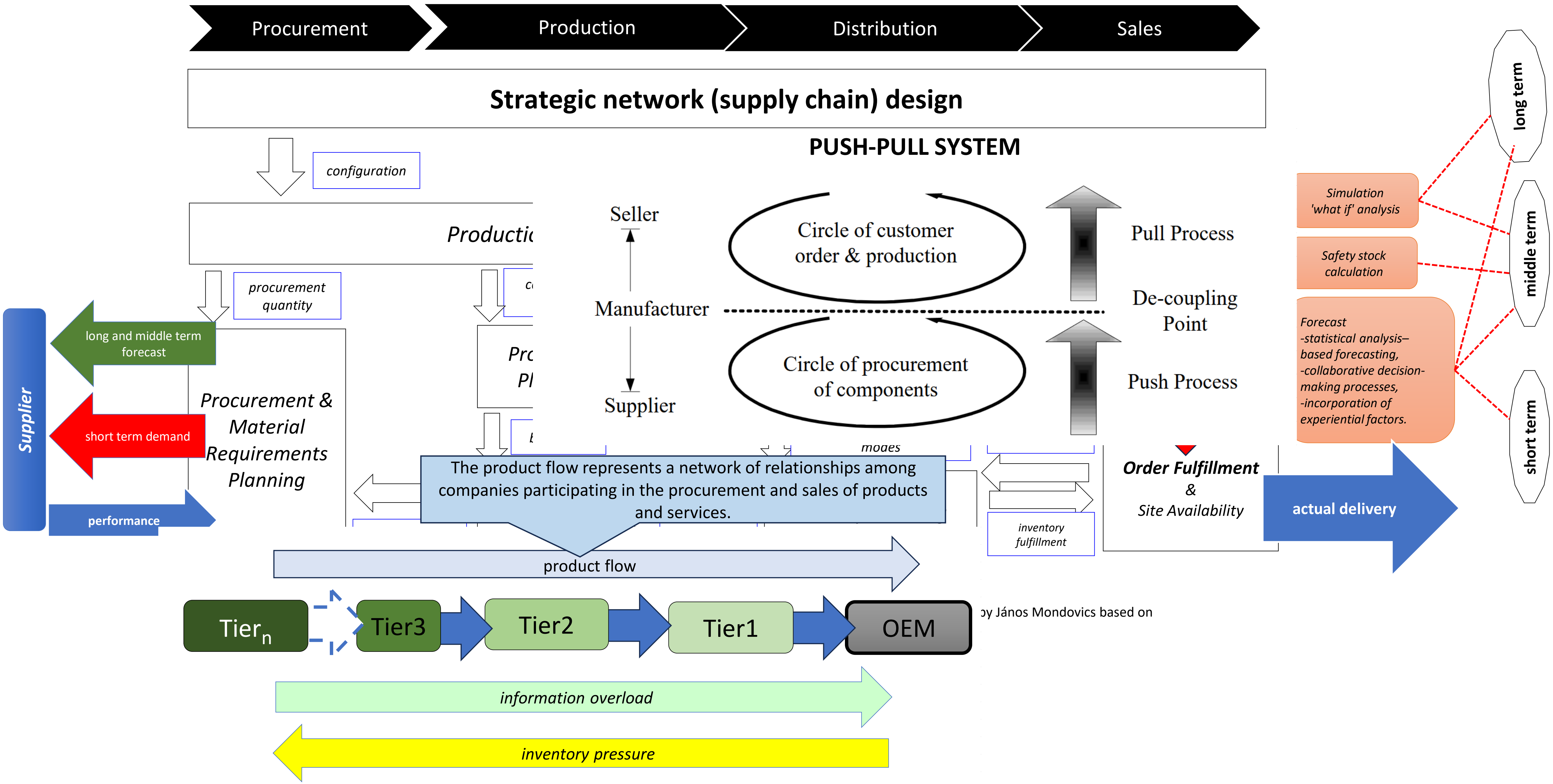
Demand forecasting in inventory planning

New elements compared to previous definitions.

"Th… y chain i… elated to the **production** … **y of a pro** … *er's supplier* to the *final* … The four main processes — **planning**, **sourcing**, **manufacturing**, and **delivery** — that define the supply chain include ***demand and supply management***, ***procurement*** of raw materials and components, ***production***, ***assembly***, ***inventory management***, ***order processing***, ***distribution***, and ***delivery to the end customer***."

*Source: Supply Chain Council (**1997**)*

AREAS OF CONFLICTS



by János Mondovics based on

HOW MUCH IS YOUR FORECAST ACCURACY WORTH?

As a consultant, I am often asked this question **:**

- *Why should we improve forecast accuracy?*
- *What is it worth to us?*
- *What is the business case for investing in process improvements and implementing expensive demand planning software?*

Yet, year after year, more and more companies employ **demand planners** and invest millions in **processes** and **software.**

We can better understand the relationships through the **service–cost trade-off model.**

Improving demand forecasting directly affects at least **three key factors.**

Revenue growth (top-line growth): improves customer service and delivery performance, which increases sales; reputation and service quality are key factors—if customers are satisfied, they remain loyal.

Profit growth through process efficiency: optimal inventory management reduces stock levels, minimizes the accumulation of obsolete goods, and enables production to match demand precisely.

Elimination of unnecessary process costs: reduces emergency shipments and overtime that would otherwise arise due to unpredictable demand fluctuations.

If we try to **quantify** the issues of forecast accuracy, the first factor is difficult to measure directly.

How much sales have we lost? Have we lost customers because of this?

What is the impact of a one-percentage-point decrease in service level and profit?

HOWEVER, SAVINGS RELATED TO INVENTORY ARE MUCH EASIER TO QUANTIFY.

AT ANY GIVEN POINT IN TIME, INVENTORY LEVELS CONSIST OF TWO MAIN COMPONENTS:

It manages demand and supply uncertainties

Safety stock

Safety stock = Forecast error * Service level factor * √Lead time

Relationship between the **reduction of safety stock and the reduction of forecast error**: since forecast error is a multiplicative factor in the safety stock formula, every percentage-point decrease affects the required inventory level.

----

the effect of reducing forecast error by one unit

Effect = Service level * √Lead time

or example, with a **98% service level** and a **two-month lead time**

Effect = 2,053 * sqrt(2) = 2,053 * 1,41 = 2,89 unit

Required inventory

covers standard demand requirements

Average stock level

Average inventory = Safety stock + demand during lead time (or, in a min–max system, the

But what is the **impact of a one-percentage-point decrease in MAPE**?

If the current MAPE is 50%, then every 1% improvement in forecast error results in a 2% reduction in inventory.
If the current MAPE is 25%, then every 1% improvement reduces inventory levels by 4%.

Here, the **minimum savings** from improved forecast accuracy come from the **reduction in safety stock**; however, in reality, better forecasting also enables **more efficient inventory management** to cover demand during lead time.

This is a **conservative estimate**, as it only considers the reduction in **safety stock** within total inventory. If the forecast **overestimates** demand during lead time, the company holds **excess inventory** that is not accounted for in this calculation. This also introduces **obsolescence risk**, which may result in unsold inventory becoming a **total loss**.

Service level:	90%	91%	92%	93%	94%	95%	96%	97%	98%
Service level constant	1,281552	1,340755	1,405072	1,475791	1,554774	1,644854	1,750686	1,880794	2,053749

A PRACTICAL EXAMPLE

Assume that:
- the company's inventory is HUF 200 million,
- its safety stock is 25%, i.e. HUF 50 million.

It does not take into account:
• the further reduction in inventory resulting from **better estimation of demand** during lead time.
• the reduction in **obsolescence risk**, which further mitigates financial losses.

If MAPE decreases by **10 percentage points**, then:
• a **20% reduction** in safety stock can be expected.
• this corresponds to a HUF 10 million **reduction in inventory** (50M × 20%).

What does a HUF 10 million reduction in inventory mean financially?

This depends on where the company's annual inventory holding cost falls, e.g., between 12% and 40%.

- At a 12% inventory holding cost → **HUF 1.2M** savings (*2.4% of safety stock*)
  At a 40% inventory holding cost → **HUF 4M** savings (*8% of safety stock*).

*Now **we are talking about real financial impacts!***
It's time to improve demand planning and capture these savings!

“The focus of the supply chain / logistics manager is on **inventory**…

without losing sight of customer service levels!”

(Pete Spolander, SAB)

Inventory in the supply chain

Inventory refers to the *tangible goods and assets* that an organization accumulates in order to use them in the future (at an appropriate time) within the production and distribution processes, in accordance with the required demand levels.

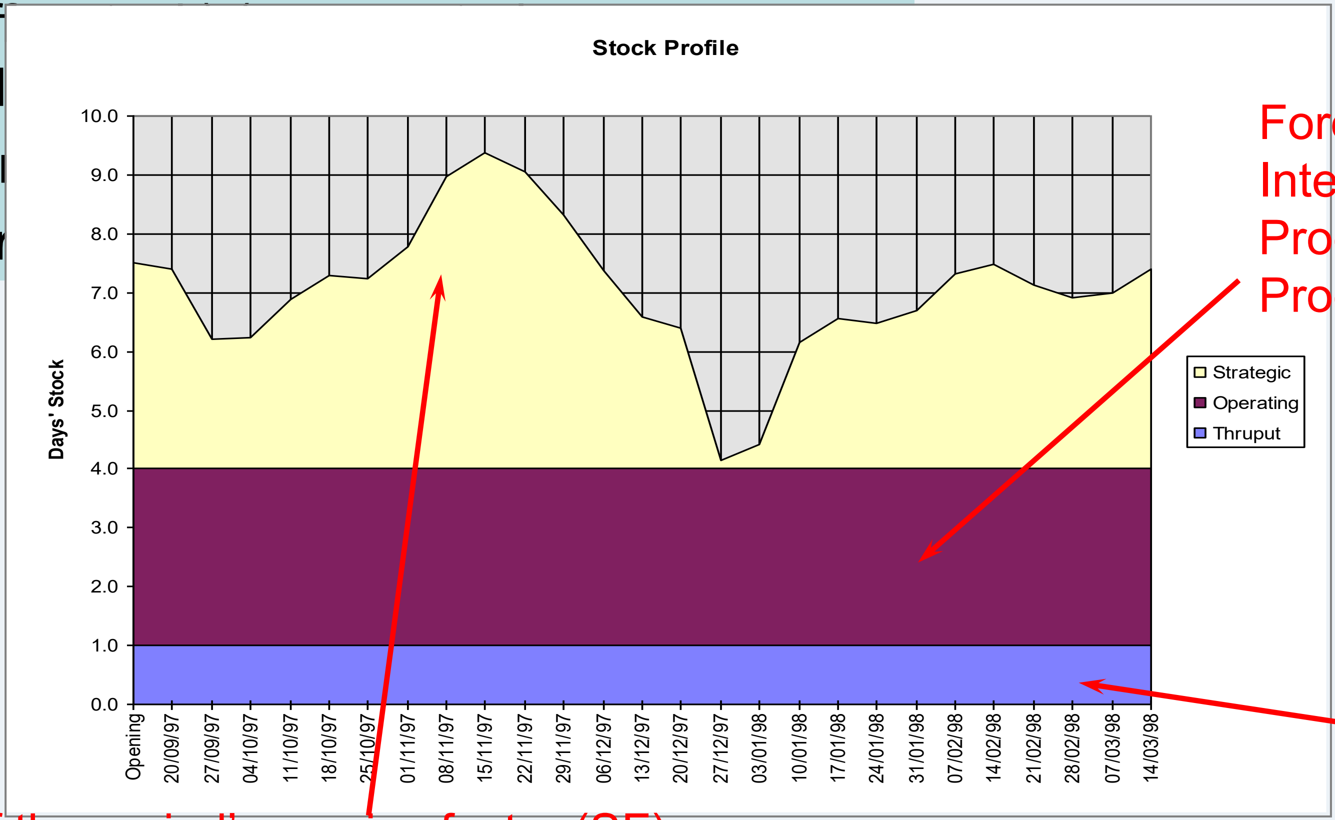
The role of inventory within the supply chain:

- achieving economies of scale,
- balancing supply and demand,
- production specialization,
- mitigating uncertainties in demand and order cycles (tactical purchasing),
- acting as a buffer at critical points in the distribution channel.

Types of inventory:

- **anticipation inventory** (seasonal demand),
- **cycle stock** (order quantity, demand between two replenishments),
- **safety stock** (buf
  demand, supply d
- **speculative inve**
- **pipeline invento**

Factors influencing inventory levels



Forecast accuracy
Inter-depot reliability/flexibility
Production reliability
Production flexibility / cycle times

Trend of the period's service factor (SF)
Average coverage of the period
Inventory cost
Number of brand-pack combinations

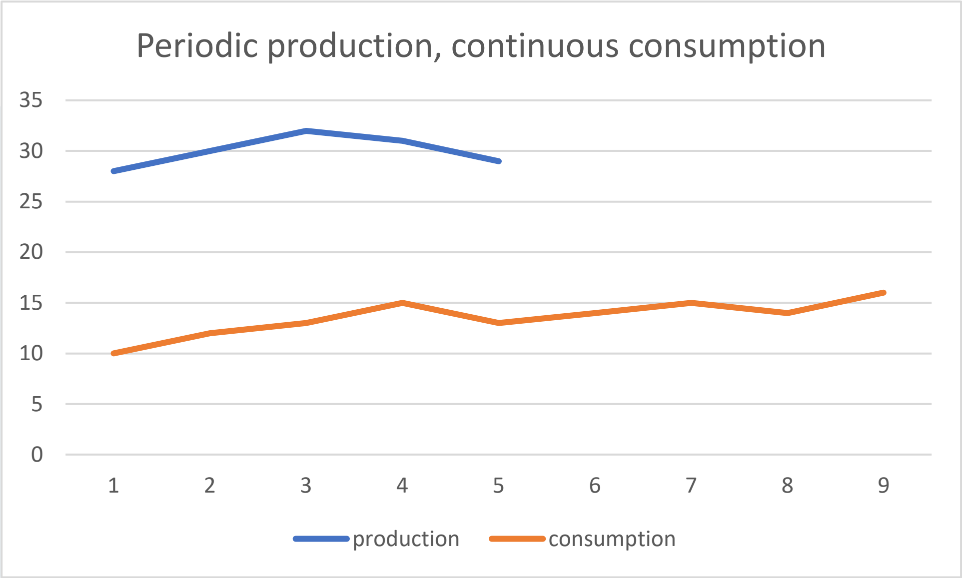
Inter-depot lead times
Bin sizes
etc.

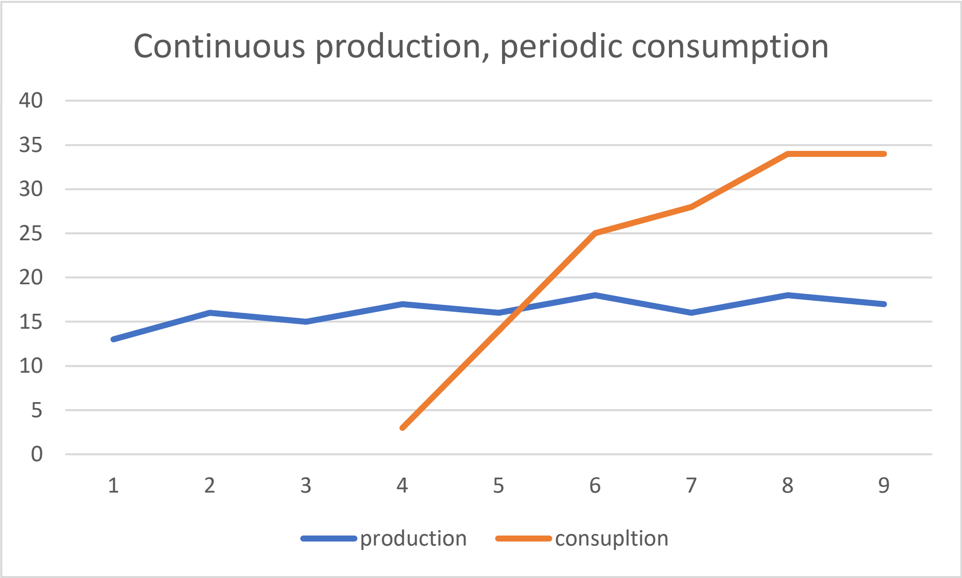
Detailed cost components of inventory management

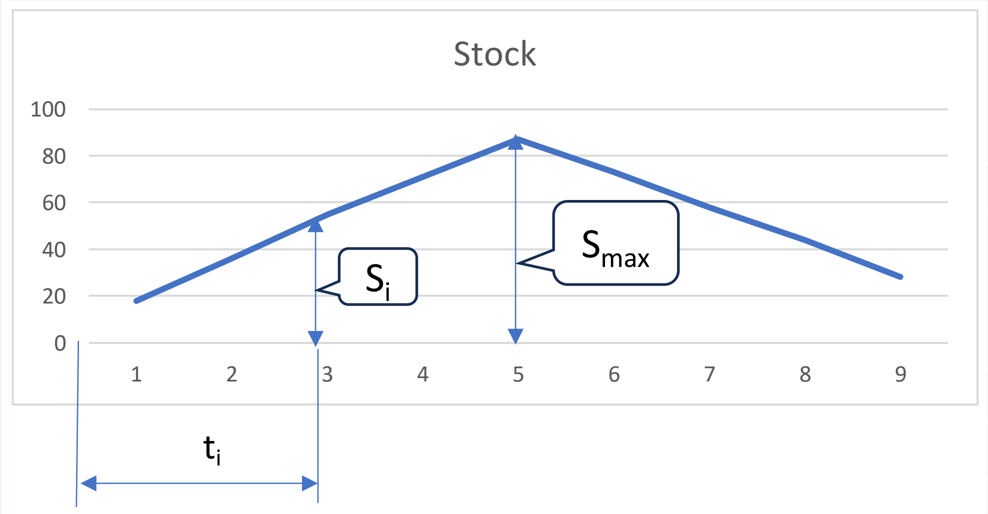
- Inventory replenishment costs (C_r)
  - Costs of procurement-related activities
  - Fees paid to the carrier (freight forwarder)
  - Damage (loss) during transportation
- Inventory holding costs (C_h)
  - Warehousing cost
    - Warehouse establishment
    - Warehouse operation
    - Storage losses
  - Inventory investment
- Shortage costs (C_s)
  - Lost or delayed revenue
  - Additional cost of emergency procurement
  - Late delivery penalties
  - Loss of goodwill

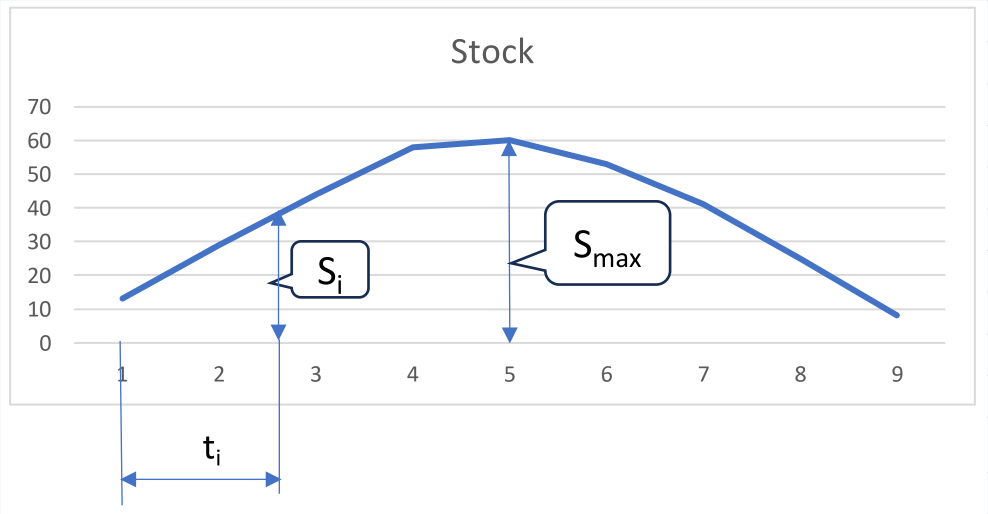
Objective: $C = C_h + C_r + C_s \longrightarrow$ MIN!

Formation of inventories







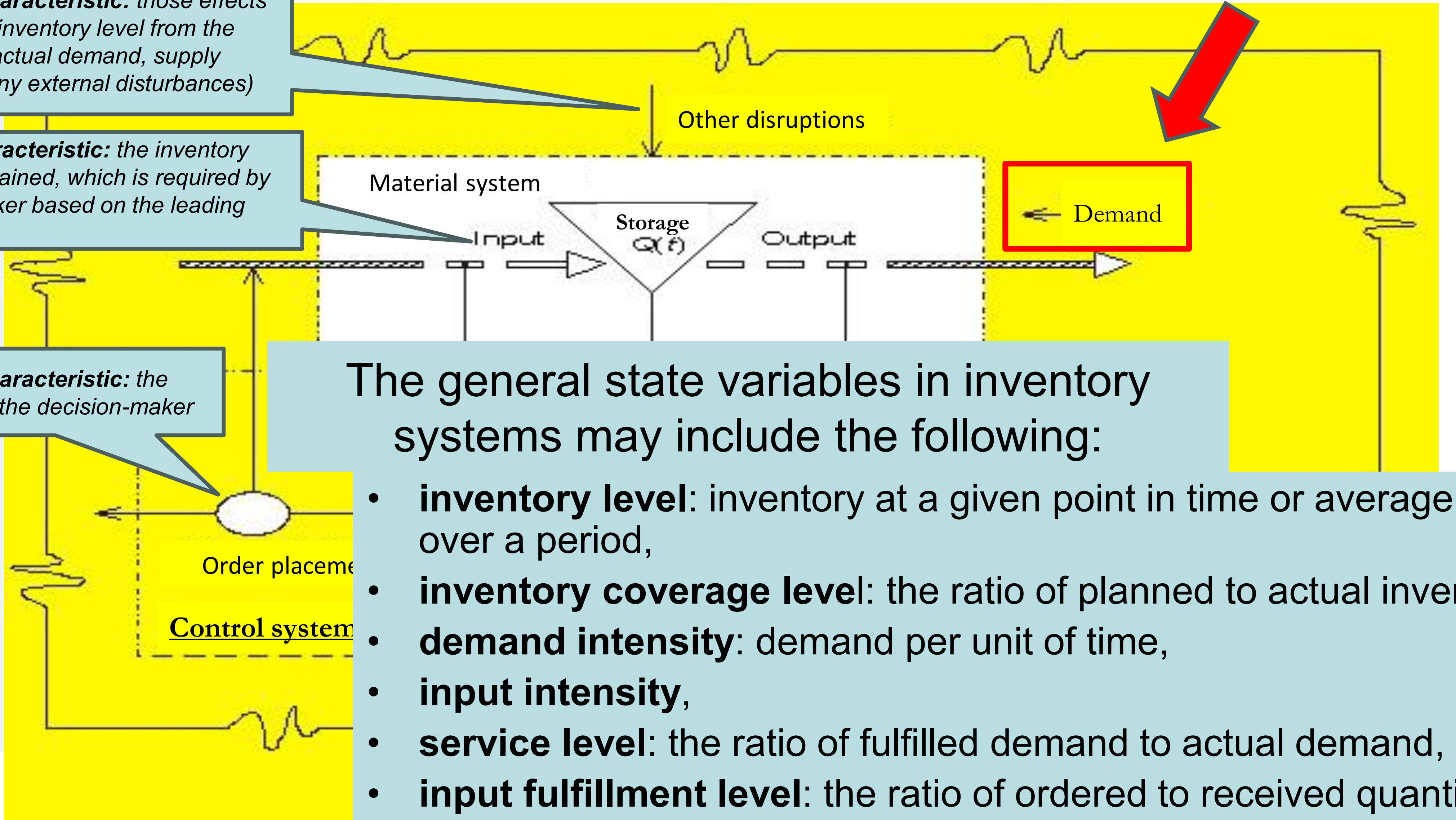


Structure of the inventory system – handling inventory changes – the control system

Disturbance characteristic: *those effects that deviate the inventory level from the planned value (actual demand, supply disruptions, or any external disturbances)*

Controlled characteristic: *the inventory level to be maintained, which is required by the decision-maker based on the leading characteristic*

Intervention characteristic: *the order placed by the decision-maker*



The general state variables in inventory systems may include the following:

- **inventory level**: inventory at a given point in time or average inventory over a period,
- **inventory coverage level**: the ratio of planned to actual inventory,
- **demand intensity**: demand per unit of time,
- **input intensity**,
- **service level**: the ratio of fulfilled demand to actual demand,
- **input fulfillment level**: the ratio of ordered to received quantities

Models and modeling

The concept of a model and the modeling process

The main stages of the modeling process:

- identification of the **need** for modeling,
- **theoretical preparation** for modeling,
- **model development** (selection),
- **model analysis**,
- **knowledge transfer**,
- **validation** and **verification** of new knowledge,
- integration of new knowled... **theory** and **practice**.

...ed or conceptually constructed ... cognition, substitutes for the ... a clearly defined relationship of ... phic relations, analogy, physical ... studying the model and ...

(V. Stoff)

The characteristics of the control system (the mechanism of inventory management) are fundamentally determined by two questions:

1. **when** és
2. **how much**

should the decision-maker order?

In inventory systems, two basic types of answers have emerged for these questions:

Two possible answers to the ***timing*** question:

- orders are placed at fixed intervals (**t**),
- replenishment is triggered when the inventory level falls below a specified minimum level (**s**).

Two options regarding ***order quantity***:

- the order quantity is fixed (**q**),
- the order quantity is such that, upon arrival, the inventory reaches a predefined maximum level (**S**).

Inve... ...inations of ...

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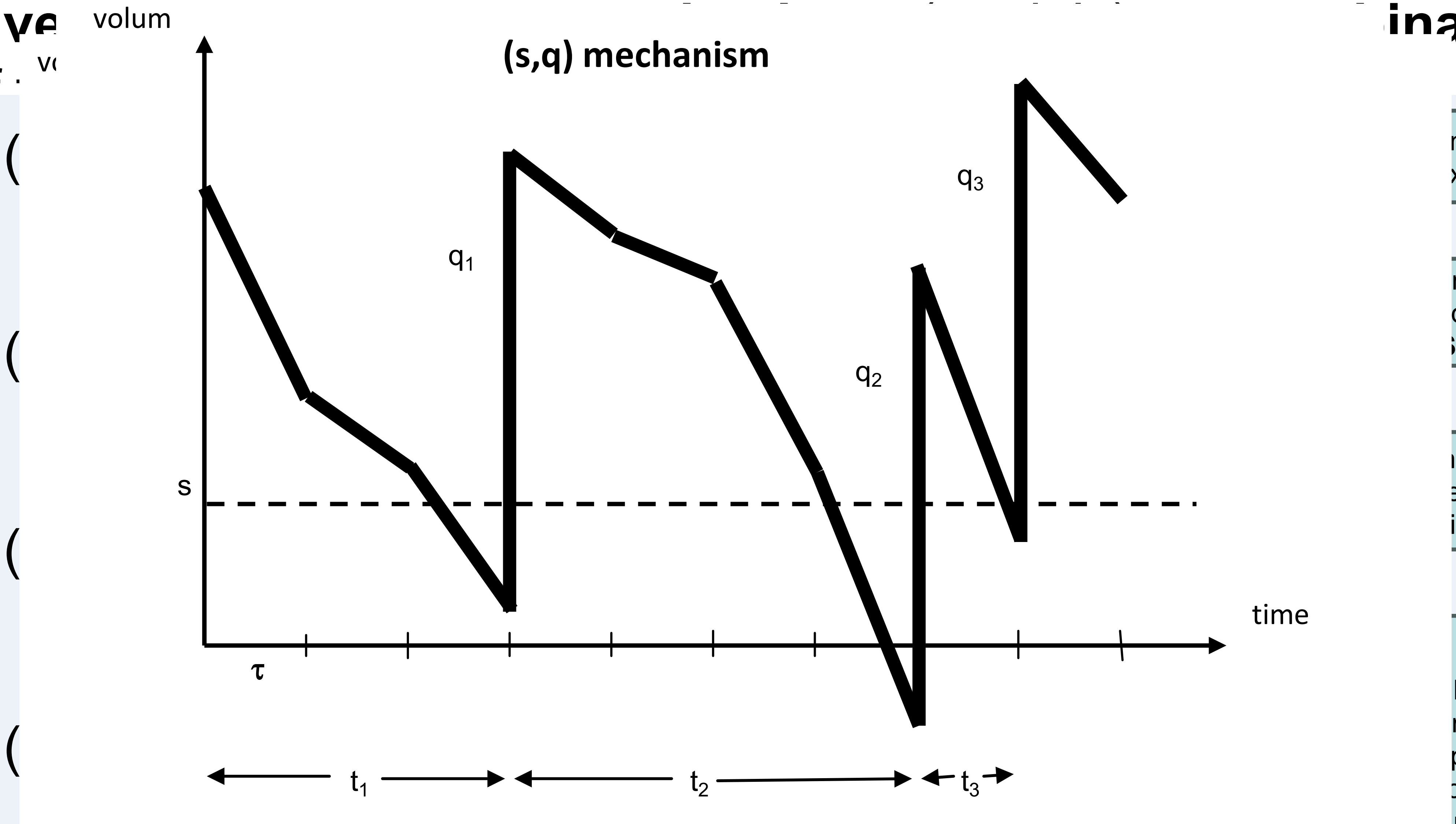


...ntervals (**t**)
...xed (**q**)

...ntervals (**t**)
...defined maximum
...)

...ventory falls below
...evel (**s**)
...ixed (**q**)

... is triggered when
... below a specified
...m level (**s**)
...placed to raise
...o a predefined
...aximum level (**S**)

EOQ (Economic Order Quantity)- the basic model

(This is therefore the order quantity that minimizes inventory-related costs.)

- D – yearly demand; pcs/yr
- C – product cost; HUF/pcs
- Q – order quantity of the product; pcs/order
- S – average ordering cost; HUF/order
- I – unit inventory holding cost; %
- H – inventory holding cost=I*C; HUF/pcs/yr
- d – daily demand; pc
- L – lead time; days/order

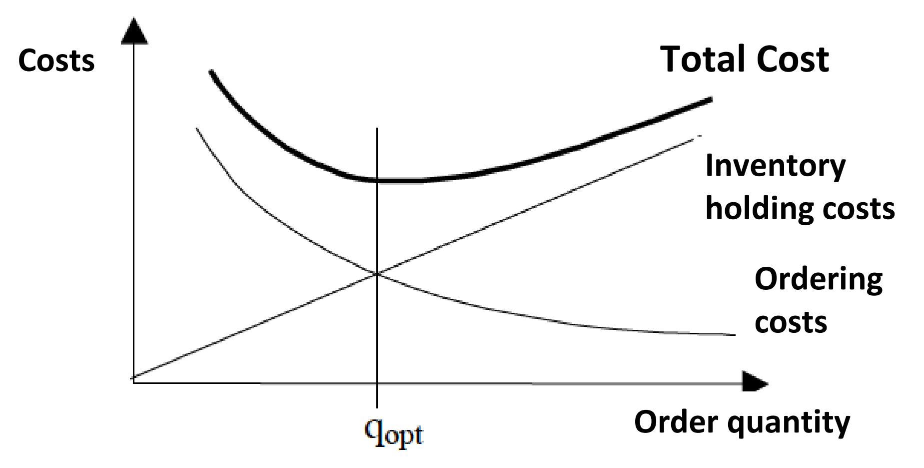
Number of orders = D / Q
Ordering cost = S * (D / Q)
Average inventory
  volume = Q / 2
  cost = (Q / 2) * C
Average inventory holding cost = (Q / 2)* I * C
= (Q / 2) * H

Total inventory cost (TSC) =
= (Q / 2) * I * C + S * (D / Q)
inventory holding cost *ordering cost*

Take the first derivative:

d(TC)/d(Q) = (I * C) / 2 – (D * S) / Q²

For the optimum: let it be d(TC)/d(Q) = 0
D*S / Q² = I * C / 2
Q² / D * S = 2 / I * C
Q² = (D * S * 2) / I * C
Q = sqrt (2 * D * S / I * C)



EOQ model equations

- D – yearly demand; pcs/yr
- S – average ordering cost; monetary unit per order
- H – inventory holding cost; monetary unit per pc
- d – daily demand; pc
- L – lead time; day/order
- ROP – reorder point; pc

Optimal order quantity:

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

Expected time between orders:

$$T = \frac{\text{number of working days per y}}{N}$$

Reorder point:

$$d = \frac{D}{\text{number of working days per year}}$$

ROP = d * L

What if…

- interest rates increase?

- order processing is automated?

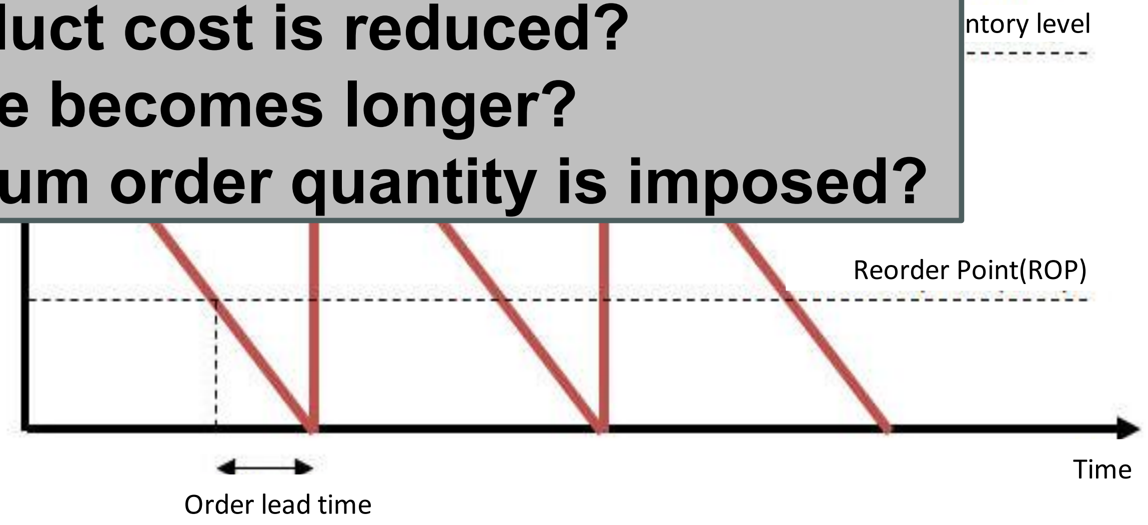
- warehousing costs decrease?

- a competing product is introduced?

- the product cost is reduced?

- lead time becomes longer?

- a minimum order quantity is imposed?



Example

- D – yearly demand; pc/yr = 800.000 pcs/yr
- S – average ordering cost; monetary unit per order = 140 EURO/order
- H – inventory holding cost; monetary unit per order = 2,5 EURO/pc/yr
- d – daily demand; pc
- L – lead time; day/order = 2 days

The optimal order quantity :

Q_{opt}=sqrt(2*D*S/H)=sqrt(2*800000*140/2,5)=
=sqrt(224.000.000/2,5)=sqrt(89.600.000)=9466 pcs

The expected length of the ordering cycle between orders :

TBO=Qopt/D=9466/800.000=0,0118 yr = 2,96 days

The expected number of orders :

N=D/ Q_{opt} =800.000/9466=84,5 orders

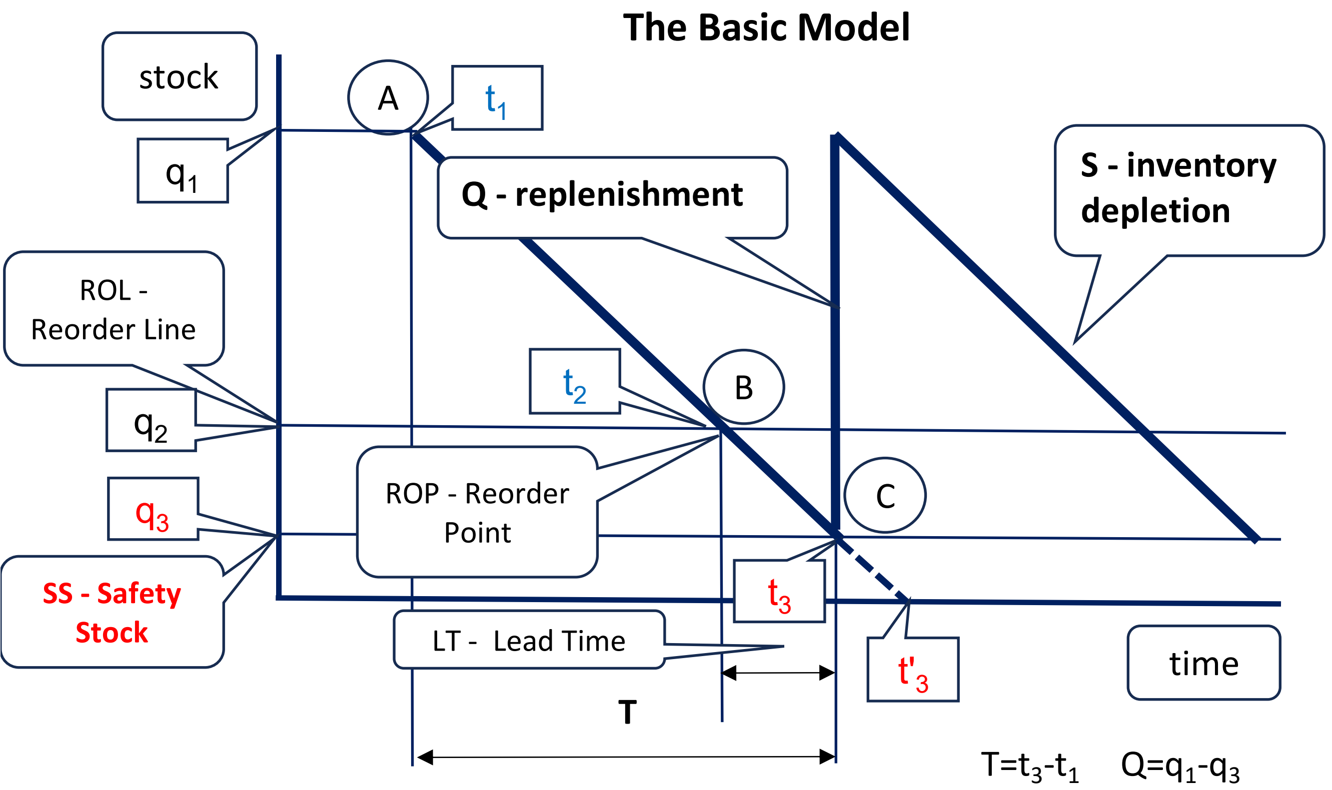
Expected time between orders :

T=251/N=251/84,5=2,96 days

Reorder point

d=D/251=800.000/251=3187 ROP=d*L=3187*2=6374 pcs

Safety stock



1

Safety stock = average sales * period covered by safety stock

$q_3 = avg(S_i) * (t'_3 - t_3)$

2

In case of demand variability :

Safety stock = (max sales * max delivery time) – (avg. sales * avg. delivery time)

$q_3 = (max(S_i) * LT_{max}) - (avg(S_i) * LT_{avg})$

3

If demand is uncertain :

Safety stock = safety factor * standard deviation of sales * square root of the average delivery time

$q_3 = sc * stdev(S_i) * \sqrt{LT_{avg}}$

4

If lead time is uncertain :

Safety stock = safety factor * avg sales * standard deviation of delivery times

$q_3 = sc * avg(S_i) * stdev(LT_i)$

5

If demand and lead time are uncertain and independent :

Safety stock = safety factor * square root((avg delivery time * standard deviation of sales)^2) + (avg sales * standard deviation of delivery times)^2)

$q_3 = sc * \sqrt{((LT_{avg} * stdev(S_i))^2) + (avg(S_i) * stdev(LT_i)^2)}$

6

If demand and lead time are uncertain and dependent :

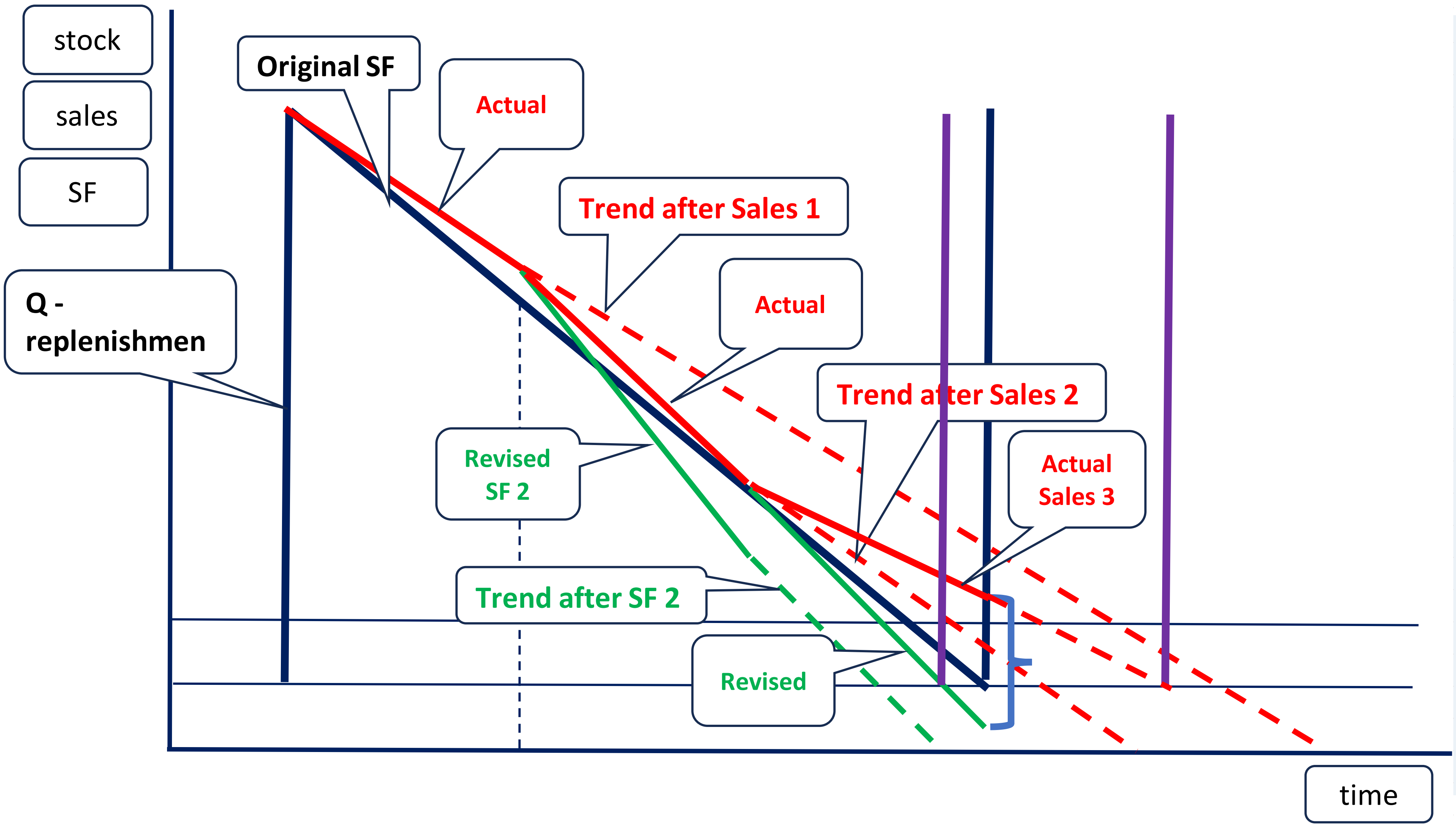
Safety stock = safety factor * ((standard deviation of sales * square root of the average delivery time) + (avg sales * standard deviation of delivery times))

$q_3 = sc * ((stdev(S_i) * \sqrt{LT_{avg}}) + (avg(S_i) * stdev(LT_i)))$

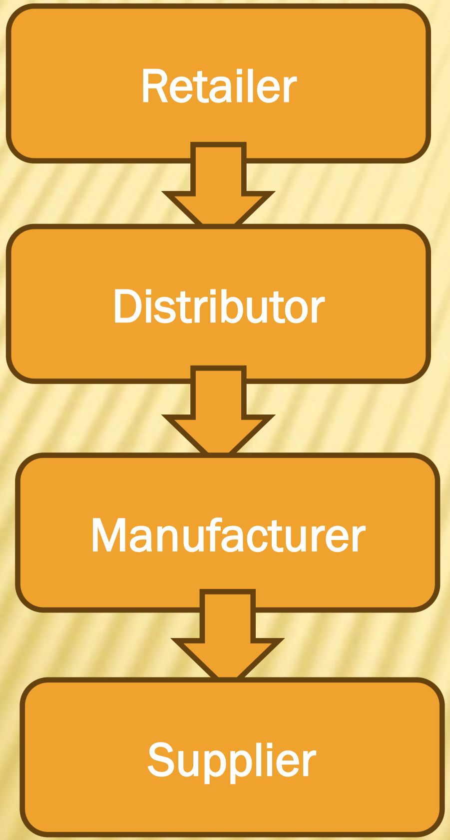
Reorder point = average sales * average delivery time + safety stock

$q_2 = avg(S_i) * LT_{avg} + q_3$

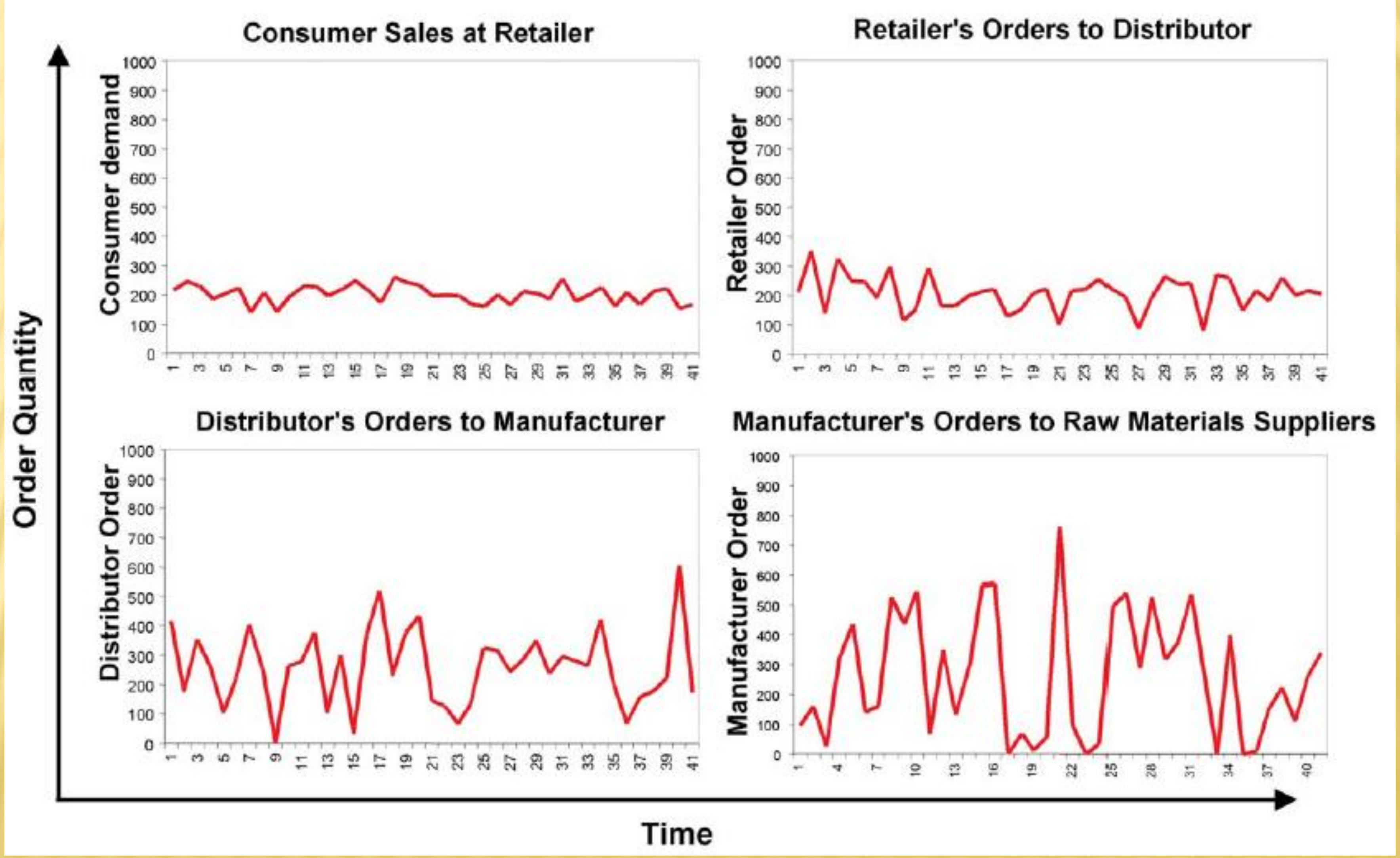
Sales – SF – Actual sales – Stock flow

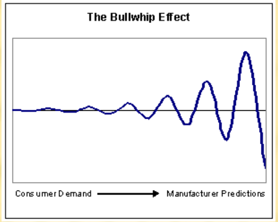


THE BULLWHIP EFFECT - ONE OF THE RISK ELEMENTS OF FORECASTING



Participants in the supply chain





Causes of the bullwhip effect (from the perspective of a given supply chain member)		
External causes		Internal causes
Supplier-side causes	*Customer-side causes*	
Supplier shortage (condition/state)	Clearance sales	Demand shifting
Change in production technology	Periodic ordering	Change in product/service
Introduction of a new input product or service	Price fluctuation	Delayed deliveries
Information / data entry errors	Information / data entry errors	Fear of stockouts
		Inaccuracy of demand forecasts
		Information / data entry errors

Adverse effects of the bullwhip effect
- inadequate inventory management → inventory holding costs increase
- backorders and low-quality output → customer service level decreases
- unpredictable production scheduling → resource utilization efficiency decreases
- transportation and warehousing costs increase
- high raw material procurement costs due to urgent demand
- lost revenue (profit)

How can we reduce the bullwhip effect?

1. **Improved information flow**, enhanced communication across the entire supply chain, and better forecasting. Building **forecasts** based on **historical data** to avoid shortages.

2. Reducing or **eliminating delays** across the entire supply chain.
According to experience and simulation studies, an 80% reduction in supply chain variability:
- halves the order-to-delivery lead time,
- reduces the **capital tied** up in inventory,
- lowers **operating costs** (less capacity is needed to handle extreme demand fluctuations).

3. **Reduction of cycle time**

4. Greater focus on **end-user demand** through *point-of-sale* (POS) data collection, *electronic data interchange* (EDI), and *vendor-managed inventory* (VMI) tools (reducing the distortion effect of downstream information flow).

5. **Collaboration** with retailers to enable **smaller order quantities**.

6. Keeping **product prices relatively stable**.
Low prices encourage customers to over-purchase, while high prices lead them to cut back on purchases (resulting in high demand variability).

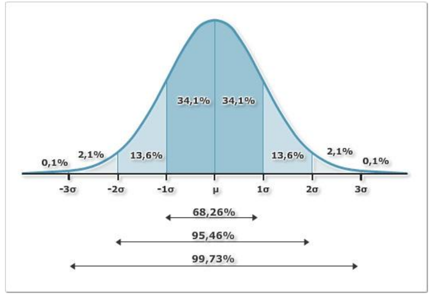
THE RELATIONSHIP BETWEEN CUSTOMER SERVICE LEVEL AND INVENTORY LEVELS

The Lokad model *(see, use and test the enclosed file: caculate-safety-stocks ENG.xls)*

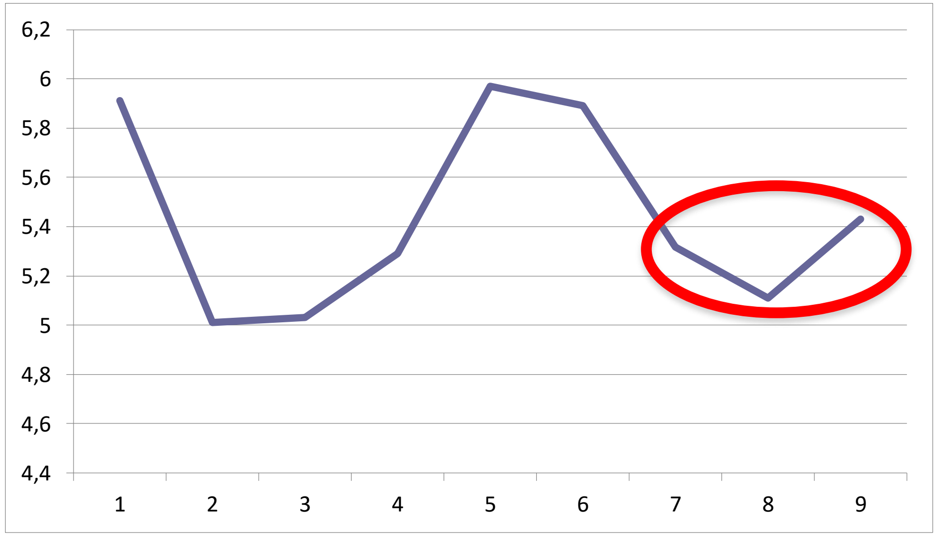
APPROACH FROM THE INVENTORY PERSPECTIVE

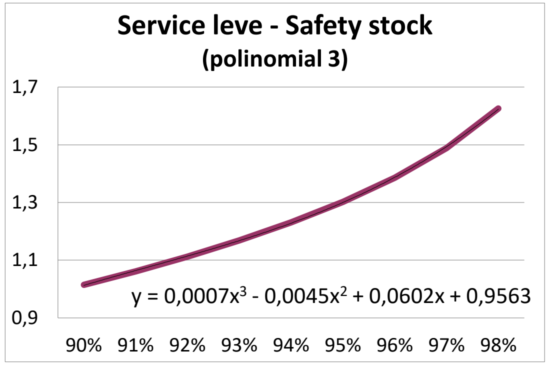
		Actual sales						Forecast			3wMA	
											a	f
Assumptions		júl.07	aug.07	szept.07	okt.07	nov.07	dec.07	jan.08	febr.08	márc.08	5,91	
		5,91	5,01	5,03	5,29	5,97	5,89	5,32	5,11	5,43	5,01	
		0,62	-0,28	-0,26	0,00	0,68	0,60		5,29		5,03	
	Lead time (month):			3							5,29	5,32
	Service level			0,98							5,97	5,11

		Value	Formula	Note	a	f
Calculations			**Formula**	**Note**	5,89	5,43
	Demand during lead time	15,856667	SUM(H4:J4)	Sum of Forecasts		5,72
	Standard deviation:	0,4570631	STDEV(B5:G5)	Standard deviation of actual sales		
	Service level	**2,0537489**	NORMSINV(D7)	Inverse of the normal distribution		
	Lead time factor	1,7320508	SQRT(D6)	Square root of the lead time for the forecast		
	Safety stock	**1,6258637**	D10*D11*D12	Component factors		
	Reordering point	17,48253	D9+D13	demand during lead time + safety stock		



			90%	91%	92%	93%	94%	95%	96%	97%	98%
	Service level:		90%	91%	92%	93%	94%	95%	96%	97%	98%
A	Safety stock		1,014549	1,061417	1,112334	1,16832	1,230847	1,302159	1,385942	1,488942	1,625864
B	**Reordering point**		16,87122	16,91808	16,969	17,02499	17,08751	17,15883	17,24261	17,34561	17,48253
		A/B (%)	6,0%	6,3%	6,6%	6,9%	7,2%	7,6%	8,0%	8,6%	9,3%
	Service level:		90%	91%	92%	93%	94%	95%	96%	97%	98%
	Service level constant		1,281552	1,340755	1,405072	1,475791	1,554774	1,644854	1,750686	1,880794	2,053749





SERVICE LEVEL (1)

For ***measuring inventory management performance*** in supply chain management and inventory control

From the optimal solution of these models, the optimal level of unfulfilled (backordered) demand can also be derived.

For the optimization approach, it is also necessary to know the **optimal level of backorder costs.**

A customer order that cannot be fulfilled on time and for which the customer is not infinitely willing to wait.

The proportion of items and the number of days are important quality indicators of a company's customer service performance and the efficiency of its inventory management practices.

The inventory performance of a stocking node within the supply network can be determined using technical performance measures (target values are set by the decision-maker).

The definition of the service level may depend on:
- the location/region,
- the products considered,
- the relevant time interval.

Supply chain processes cannot be optimized:
- if performance metrics are not continuously monitored,
- if the controlling tasks related to the performance of a stocking node are neglected.

SERVICE LEVEL (2)

Type II service level (β service level)

$$\beta = 1 - \frac{\text{orders expected to be unfulfilled during the period}}{\text{expected demand during the period}}$$

- **quantity-oriented performance measure**
- **indicates the occurrence of a stockout,**
- also indicates the **quantity** of unfulfilled (backordered) orders,
- widely used in industrial practice.

Type I service level (α service level)

This service level (α) is an **event-oriented performance criterion**. It measures the probability that, within a given time interval, **every customer order** can be fully fulfilled from inventory **without delay**.

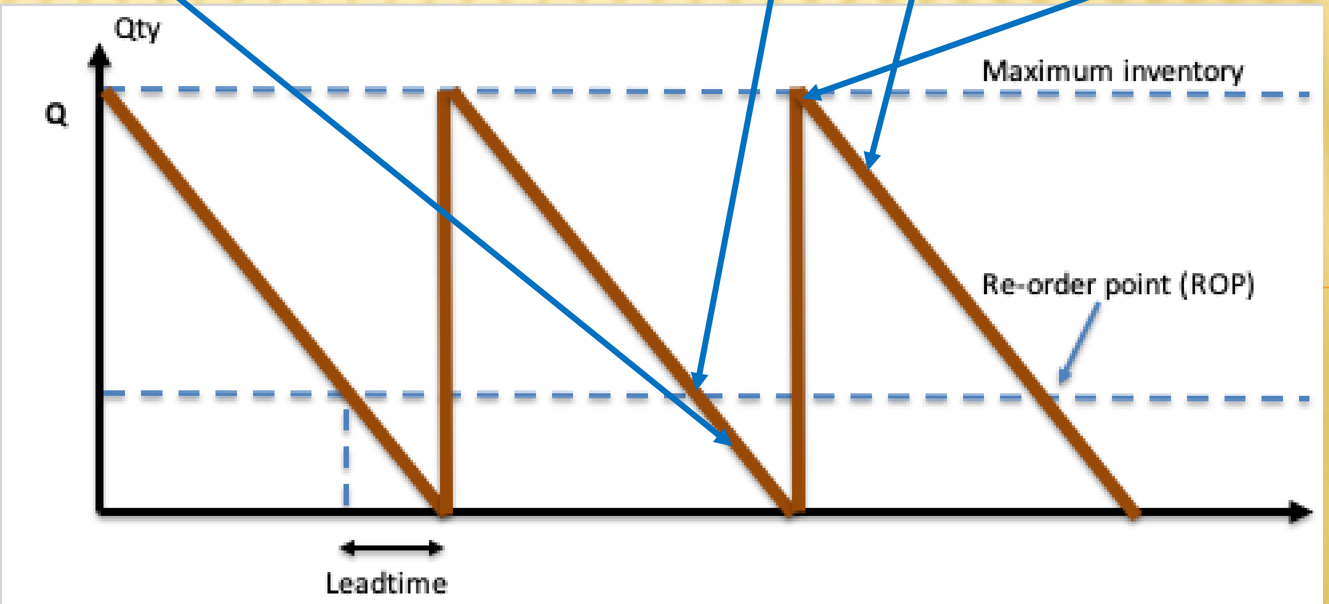
Two variants exist regarding the *time interval* of customer order arrivals.

Type 1a $\underline{\alpha}$ service level:

$\underline{\alpha}_p$ = *Probability {demand during the period ≤ inventory at the beginning of the period}*

Type 1b $\underline{\alpha}$ service level:

$\underline{\alpha}_c$ = *Probability {demand during the replenishment lead time ≤ inventory at the beginning of the lead time}*



KPIS USED IN PRACTICE BY THE PARTICIPANTS

RELATED PERSPECTIVES (1): INTERACTIONS BETWEEN THE SUPPLY CHAIN AND THE DEMAND-DRIVEN CHAIN – IN THE OPTIMAL CASE

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members.

-the chain recognizes **real market demand** and responds to it,
-**forecast**-driven vs. **demand**-driven system,
-**ECR** (Efficient Consumer Response) information technology: *collection of **demand** information at the point of sale or point of consumption*.

Consequence: the **adaptive supply chain**

Efficient response to consumer demand – Efficient Consumer Response (ECR) tools

- Efficient response to **consumer** demand, representing a new form of more effective collaboration betw en **retailers** and **manufacturers**. Professionals from both manufacture retailers pply ECR methods in eir joint activities.

  tives

  produc rtment,

  ce

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- Key business activities to
  (a) **continuous replenis**
  (b) **computer assisted ordering (CAO)**;
  (c) **flow-through distribution (cross-docking)**;
  (d) **activity-based costing (ABC)**;
  (e) **category management**;
  (f) **integrated Electronic Data Interchange (EDI)**.

Benefits for the consumer
-greater variety and convenience,
-purchasing aligned with customer needs,
-reduced stockouts,
-more fresh and lower priced products.

Benefits for the retailer
-increased customer loyalty,
-improved market research,
-better relationship with the supplier,
-improvement of supply chain efficiency.

Benefits for the manufacturer
-efficient production,
-demand synchronization,
-less stock-out,
-stronger product position,
-more durable business relationships.

Category management is an optimization process aimed at maximizing sales and profit, focusing on a group of brands—known as a category—rather than on individual items or brands.

VENDOR-MANAGED INVENTORY (VMI)

Vendor Managed Inventory (VMI) is the most advanced form of Continuous Replenishment (CR) systems, where the supplying company:

completely independently,

based on information from the user and other sources,

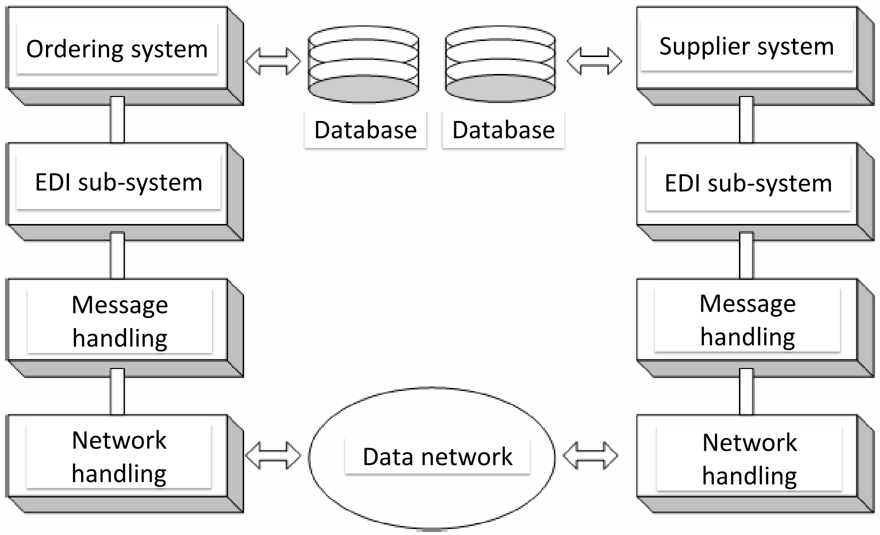
- monitors and
- replenishes the user's warehouse,

the full availability of inventory is ensured by the supplier,

responsibility and control also lie with the supplier.

VMI: THE MANUFACTURER DIRECTLY SENSES MARKET FLUCTUATIONS

EDI -Electronic Data Interchange: electronic exchange of structured data based on agreed standards (clearly defined content, enabling problem-free and unambiguous information exchange)



Sharing produc
information wi
- online, or
- once a day (e.g

EDI

POS

(Consignment) inventory

Inventory replenishment

Historical sales data

analysis by product

Controlling

Planning sales promotions

Communicating demand to the product supplier

VMI
Vendor Managed Inventory

Evaluation of information on the manufacturer's side.

Conclusions / implications:
- inventory is available on time,
- optimal organization of the production schedule

producer

EDI security model
- the data/document is generated by the **sending party**,
- both the protected document and the digital signature identifying the document are sent to the **receiving party** either *together* or *separately*,
- the recipient then **verifies** the electronic data/document.

Finally... (a short overview – based on AbcSupplyChain's support)