INVENTORY MANAGEMENT IN SUPPLY CHAIN

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Inventory management

Why do we need a stock?

What does its size depend on?

The stock is:

Material goods are purchased/produced in a larger quantities than the quantity of a temporal demand for fulfilling certain objectives

Stock storage objectives:

- Guaranteeing the production continuity
- Guaranteeing the continuity of supplies to receivers in the case of demand fluctuations

To possess or not to possess stocks?

Good to possess them as they

- Guarantee the continuity of access to goods in the case of supply continuity
- Guarantee the possibility to use the goods in the periods of their unavailability
- Ensure the required customer service level in the case of random demand fluctuations
- Ensure the required customer service level in the case of the supply timeliness uncertainty

Bad to possess them as they

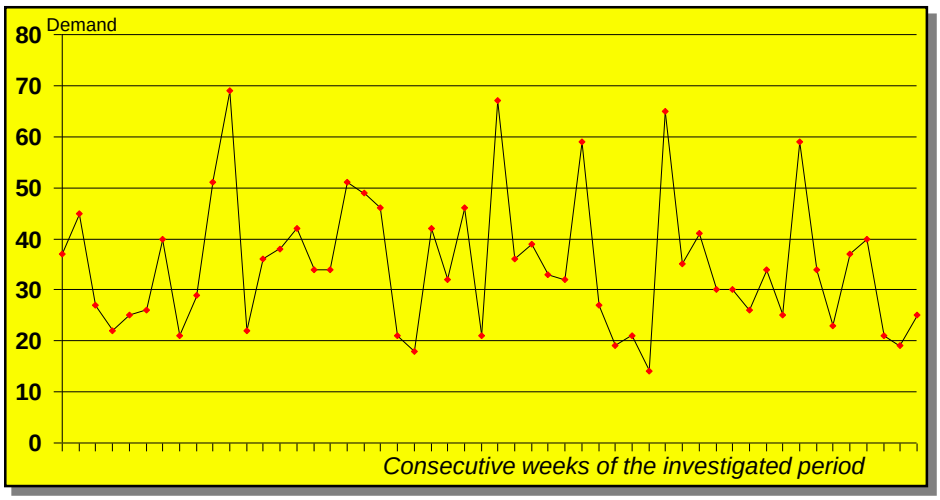
- Occupy the space (warehouses)
- Cost (place, losses, capital); Their storage (carrying) might annually cost even 20% of the purchase/produce price

Simulation of inventory replenishment processes

Demand changes in the consecutive weeks of the last year

Weeks	Demand:					
1- 6	37	45	27	22	25	26
7-12	40	21	29	51	69	22
13-18	36	38	42	34	34	51
19-24	49	46	21	18	42	32
25-30	46	21	67	36	39	33
31-36	32	59	27	19	21	14
37-42	65	35	41	30	30	26
43-48	34	25	59	34	23	37
49-52	40	21	19	25		

Demand changes in the consecutive weeks of the last year



Cost data

- Reordering cost (Fixed cost per order) K = 500 EUR
- Purchase unit price P = 300 EUR
- Coefficient of an annual stock storage cost h/P=30%

Activity objectives

- Quantity-oriented Customer Service Level as high as minimum 98%
- Minimum reordering and storage costs

Initial conditions:

- Initial stock IS= 200 units
- No order was previously made.

Week	Supply	Stock at the beginning of the week	Demand	Sales	Stock at the end of the week	Orders	Out of Stock
No.	Sup.	BS	D	Sal.	ES	O	OOS
1		800	180	180	620		
2		620	160	160	460	600	
3		460	170	170	290		
4		290	130	130	160		
5		160	150	150	10		
6	600	610	190	190	420	600	
7		420	180	180	240		
8		240	160	160	80		
9		80	170	80	0	600	90
10	600	600	200	200	400		
11		400	.....	.....	.....		

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Simulation conclusions

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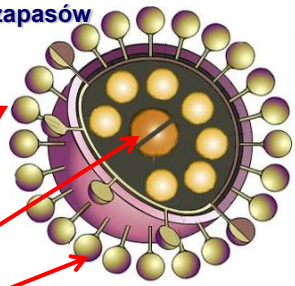
Inventory Replenishment System Problems Virus

Wirus problemów systemu odnawiania zapasów

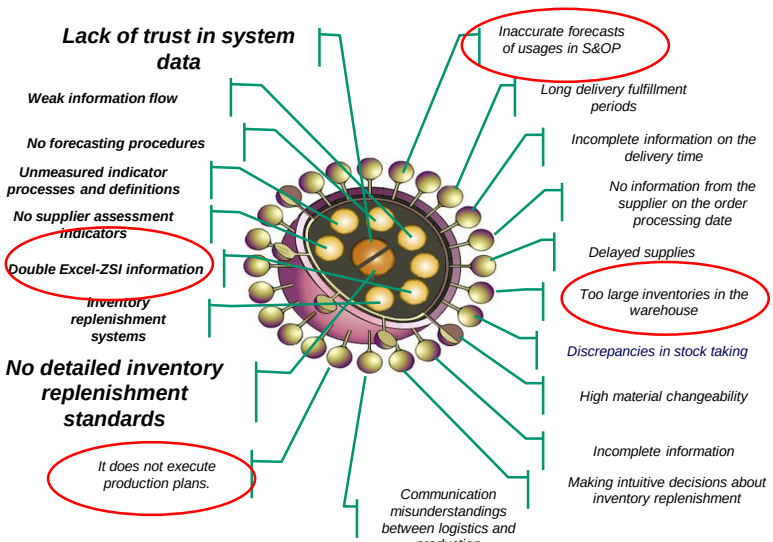


The problems in inventory replenishment systems might be visually reflected by an Inventory Replenishment System Problems Virus.

It is bulit of a central element called a virus core and internal and external coats.

The virus core reflects root causes. In the internal coat there are major prombles which influence the decrease in an enterprise's production system efficiency. The external coat is made of flaps. They symbolise the syptoms of appearing inventory replenishment system problems.

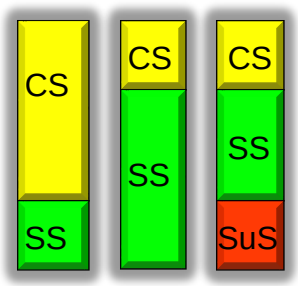
Example of the Inventory Replenishment System Problems Virus



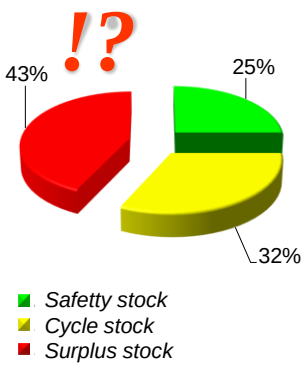
What are the virus activity effects?

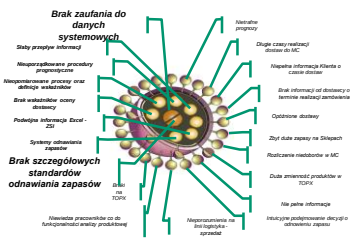
Inventory structure

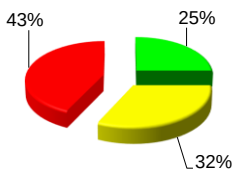
Total average inventory
- **– cycle stock (CS)**
- **– safety stock (SS)**
- **– surplus stock (SuS)**



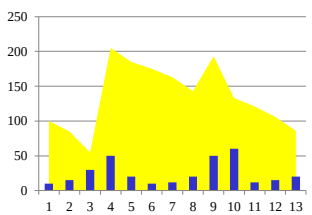
Sample situation







Safetty stock
Cycle stock
Surplus stock



Levek of the stock
Level of the seles

The surplus stock is from 10% to 30 % in most Polish production enterprises (over 85%).

Source: the author''s own unpublished research

Stock replenishment systems

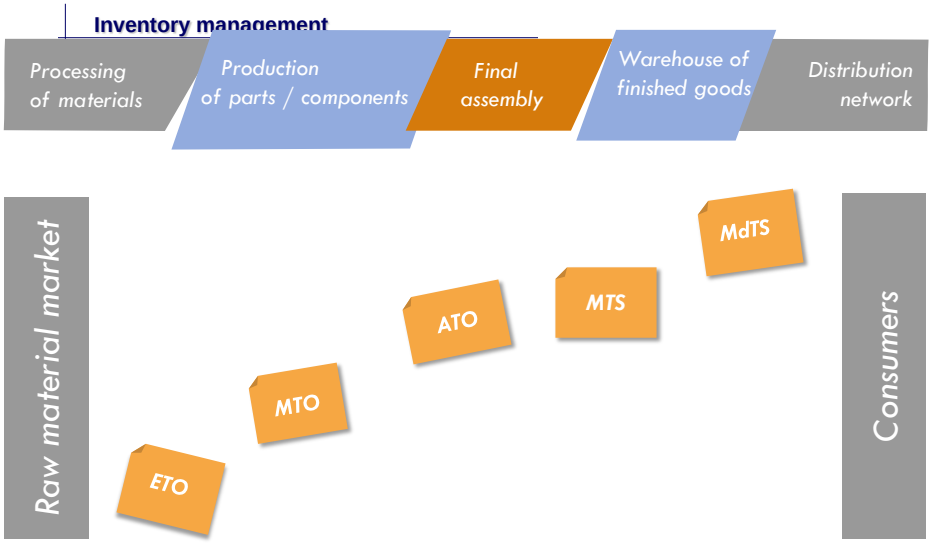
The decoupling point is a place in the process of adding value, from which a product is related to a particular customer's order. Therefore, it separates the part of the value chain controlled by the customer's order from the parts controlled by forecasts.

[Skipworth H. Harrison A., (2006), "Implications of form postponement is manufacturing a customized product", International Journal of Production Research, Vol.44, No.8, 1627-1652, p.1629]

What is the process of adding value?

It is a sequence of activities undertaken in a supply chain (by one or more organizations) which aims at providing a product or service satisfactory from the perspective of the customer's needs

Inventory management



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Goods are already in the distribution network. The customer can go to the store and purchase them without waiting for them. The customer must choose from the available goods of specified configuration. It is not possible to further adapt them to the customer's needs.

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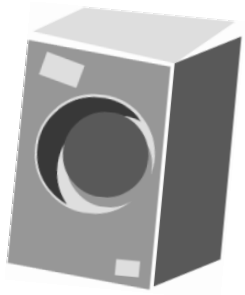
Inventory management

MTS

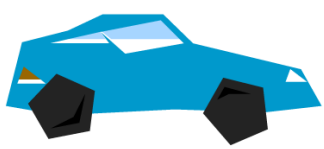
MTS - "Make to Stock" *is based on the forecasted sales of a given product. Manufactured according to a production plan, products go to the warehouse from where they can be released for clients. In this model, customers do not have a direct impact on the technical specification of the product they buy.*



Inventory management

ATO

The location of the decoupling point prior to assembly ***(ATO – "Assemble to Order")*** *entails the production of components to spare. The assembly of finished products is triggered by an order placed by the customer. The manufactured components are standard. The product is adjusted to the customer's requirements at the stage of assembly. Typically, the assembly stage in the ATO model is much less labour-intensive than the production of components. Due to differences in the labour-intensity of different production stages before and after the decoupling point, the assembly of products usually begins when the set of components is available*



Inventory management

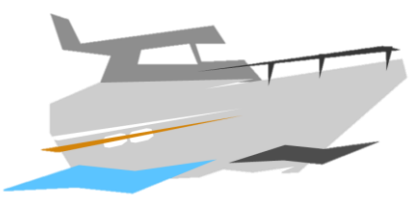
MTO

In the MTO model **("Make to Order")** the manufacturing of a product starts only after an order is placed by the customer. The company collects raw materials necessary for the production of the ordered product

Inventory management

ETO

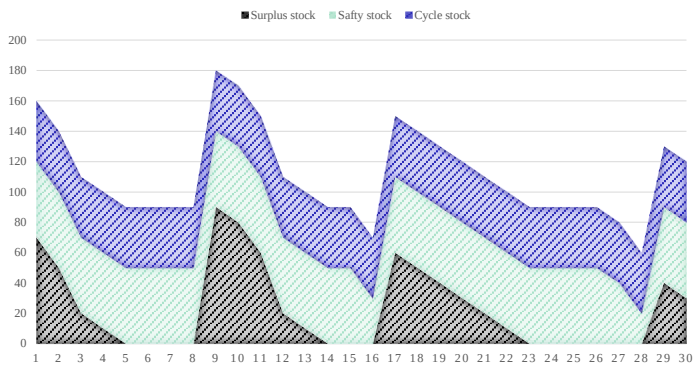
This **(ETO – "Engineer to Order")** is a model in which a product is developed on the customer's order. The buyer receives a product perfectly suited to his needs, but the waiting time for its delivery is relatively long.



Inventory management

The structure of stock tells how much of particular components are there in the current state of the stock (in terms of quantity or value) , namely: the cycle stock, the safety stock and the surplus stock.

Components of the structure of stock



Inventory management

Cycle stock - known also as rotating. Stock arises as result of cycle deliveries. It is issued to satisfy the current needs of clients. It is used for the execution of customer orders between successive deliveries. It is sufficient to satisfy the needs of customers if the demand does not exceed the average demand and the lead time does not exceed the one assumed in parameters replenishment system.

Safety stock *- non-rotating stock used when the demand in the replenishment cycle is greater than the demand assumed in the parameters of the replenishment cycle or when the lead time is longer than usual. The objective of the safety stock is to ensure the availability of goods in the conditions of changing demand and changing lead time. This leads to increasing the level of customer service.*

Surplus stock *- non-rotating stock which exceeds the needs defined by the average demand in the replenishment cycle and the assumed level of customer service. Maintaining this stock is an unjustified expense for the company.*

CYCLE STOCK

$$CS = \frac{1}{2}\overline{OQ}$$

CS - cycle stock

$\overline{OQ}$ *- the average size of the delivery (order quantity)*

It is assumed that just before accepting a delivery the cycle stock is 0 and its consumption in the cycle between supplies is uneven.

SAFETY STOCK

$$SS = \omega \cdot \sigma_{PT}$$

The safety factor is a direct result of the level of customer service in the probabilistic approach. There are two ways of determining its value.

SAFETY STOCK

Statistical tables

Knowing the value of the cycle service level you can read the value of the safety factor

POP - cycle service level

POP	ω	POP	ω	POP	ω	POP	ω
50,00%	0,000	90,50%	1,311	97,20%	1,911	99,55%	2,612
55,00%	0,126	91,00%	1,341	97,40%	1,943	99,60%	2,652
60,00%	0,253	91,50%	1,372	97,60%	1,977	99,65%	2,697
65,00%	0,385	92,00%	1,405	97,80%	2,014	99,70%	2,748
70,00%	0,524	92,50%	1,440	98,00%	2,054	99,75%	2,807
72,00%	0,583	93,00%	1,476	98,10%	2,075	99,80%	2,878
74,00%	0,643	93,50%	1,514	98,20%	2,097	99,85%	2,968
76,00%	0,706	94,00%	1,555	98,30%	2,120	99,90%	3,090
78,00%	0,772	94,50%	1,598	98,40%	2,144	99,91%	3,121
80,00%	0,842	95,00%	1,645	98,50%	2,170	99,92%	3,156
81,00%	0,878	95,20%	1,665	98,60%	2,197	99,93%	3,195
82,00%	0,915	95,40%	1,685	98,70%	2,226	99,94%	3,239
83,00%	0,954	95,60%	1,706	98,80%	2,257	99,95%	3,291
84,00%	0,994	95,80%	1,728	98,90%	2,290	99,96%	3,353
85,00%	1,036	96,00%	1,751	99,00%	2,326	99,97%	3,432
86,00%	1,080	96,20%	1,774	99,10%	2,366	99,98%	3,540
87,00%	1,126	96,40%	1,799	99,20%	2,409	99,985%	3,615
88,00%	1,175	96,60%	1,825	99,30%	2,457	99,990%	3,719
89,00%	1,227	96,80%	1,852	99,40%	2,512	99,995%	3,891
90,00%	1,282	97,00%	1,881	99,50%	2,576	99,999%	4,265

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Inventory management

SAFETY STOCK

$$SS = \omega \cdot \sigma_{PT}$$

Deviation of demand in the replenishment cycle depends on many factors. It is the same as the standard deviation of demand. However, it informs us about the deviation of demand not in the unit of time but in the lead time.

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STOCK SAFETY - DEMAND DEVIATION IN THE STOCK REPLENISHMENT CYCLE

CONDITION: Variable demand, variable lead time

$$\sigma_D > 0 \qquad \sigma_T > 0$$

$$\sigma_{DT} = \sqrt{\sigma_T^2 \cdot D^2 + \sigma_D^2 \cdot T}$$

σ_D - standard deviation of demand

T - lead time

σ_T - standard deviation of the lead time

D - average demand in a unit of time

SURPLUS STOCK

$$SurS = ASr - SS - CS$$

SurS - surplus stock
AS - average stock
SS - safety stock
CS - cycle stock

The size (or value) of the average stock can be obtained from the information system report supporting inventory management

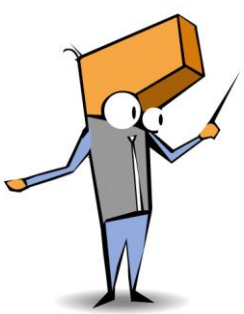
Before discussing inventory replenishment policies, we need to explain the notion of **free stock**.

Free stock, also known as disposable stock, is stock that can be released to customers (external or internal) at present or in the foreseeable future. Therefore, free stock includes stock that has been ordered from suppliers but has not yet been delivered. It will, however, be delivered in the foreseeable future and it will increase stock on hand. Disposable stock does not include goods that have been purchased by an external customer or reserved by an internal customer, but have not physically left the warehouse.

How to calculate free stock?

$$FS = SoH + SO - SR$$

FS - free stock
SoH - stock on hand
SO - stock ordered (not delivered)
SR - stock reserved (but not released from the warehouse)



Remember that free stock is used in stock replenishment to determine order timing and order quantities.

The actual release of goods from a warehouse is based on stock on hand. You can't release something that has been ordered, but is not physically in the in the warehouse.

Stock replenishment systems

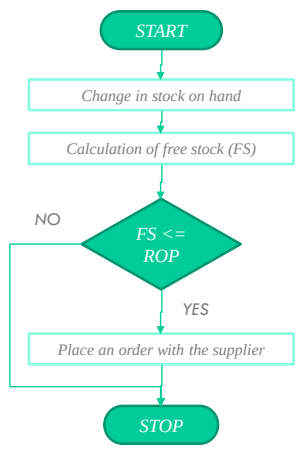
In the classic approach, we distinguish between two types of stock replenishment system:

The continuous review system, *also called the perpetual review system or the fixed-order-quantity system*

The periodic review system, *also called the fixed-time-period system*

Continuous review systems

- *In the continuous review system, information on &*disposable stock is available on an ongoing basis. Whenever stock on hand changes, a reservation is made for materials or an order is placed with a supplier, the current level of &*disposable stock is calculated.*
- *The fundamental parameter of the system is the &*reorder point. It's a value against which the &*disposable stock is compared whenever it changes.*
- *An order is placed with a supplier when the level of &*disposable stock is equal to or falls below the reorder point.*



Continuous review systems

- *To successfully use the system, we need to calculate the *reorder point properly:*

$$ROP = D \cdot T + SS$$

Remember that the same unit of time must be used for the average demand and the replenishment cycle!

ROP - reorder point

D - average demand per unit of time (eg. a week) may be replaced with a forecasted value - for more, see lessons on Demand Profile or Forecasting

T – replenishment lead time – for more, see lesson on Basic concepts

SS – safety stock – for more, go to Inventory Structure

Optimising order quantities in the continuous review system:

$$EOQ = \sqrt{\frac{2 \cdot D \cdot c_o}{c \cdot \mu_0}}$$

EOQ – economic order quantity

D – forecast demand

c_0 - cost per order (cost per one delivery)

c - purchase unit price (item cost)

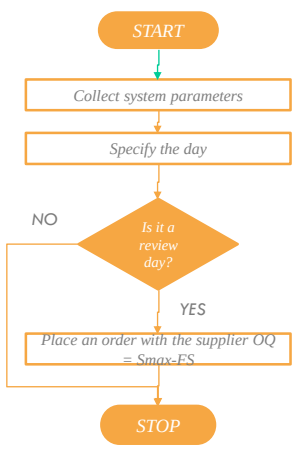
μ_0 - Inventory carring rate

What type of goods is the continuous review system recommended for?

Because of the continual record of the free stock level and the necessity to react in fluctuating periods of time, this system is recommended for the management of high-value goods and goods of great relevance to the business.

Periodic review systems

- *In the periodic review system, orders are placed at specific time intervals, denoted as T_0*
- *Orders are therefore placed regularly, e.g. once a week. On the day when an order is to be placed, inventory is reviewed and free stock is determined.*
- *The system's basic parameter is the &*maximum inventory level, i.e. the level to which the free stock determined on the day of the review is replenished.*



Periodic review systems

- *To successfully use this system, we need to determine the maximum inventory level properly:*

$$Smax = D \cdot (T + T_0) + SS$$

Remember that the same unit of time must be used for the average demand and the *review cycle time!

Smax - the maximum inventory level

D - average demand per unit of time (eg. a week) may be replaced with a forecasted value - for more, see lessons on Demand Profile or Forecasting

T – replenishment lead time – for more, see lesson on Basic concepts

T_0 - review cycle time

SS – safety stock – more on this in the lesson Inventory Structure

What type of goods is the periodic review system recommended for?

Due to the fact that the inventory level in this system is reviewed periodically, the level of stock held is slightly greater than in the continuous review system. For this reason, it's recommended for low-value goods used up at a regular pace.

Replenishment systems – a comparison

Continuous review system	*Periodic review system*
▪ *Orders placed at different time intervals* ▪ *Information on the current level of inventory available on an ongoing basis* ▪ *The basic parameter: reorder point* ▪ *Fixed order quantities*	▪ *Information on inventory available only on review days* ▪ *Orders placed at regular intervals* ▪ *Basic parameter: maximum stock level* ▪ *Order quantities change*

Stock replenishment systems - models in spreadsheet software

THANK YOU VERY MUCH FOR YOUR ATTENTION!

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