

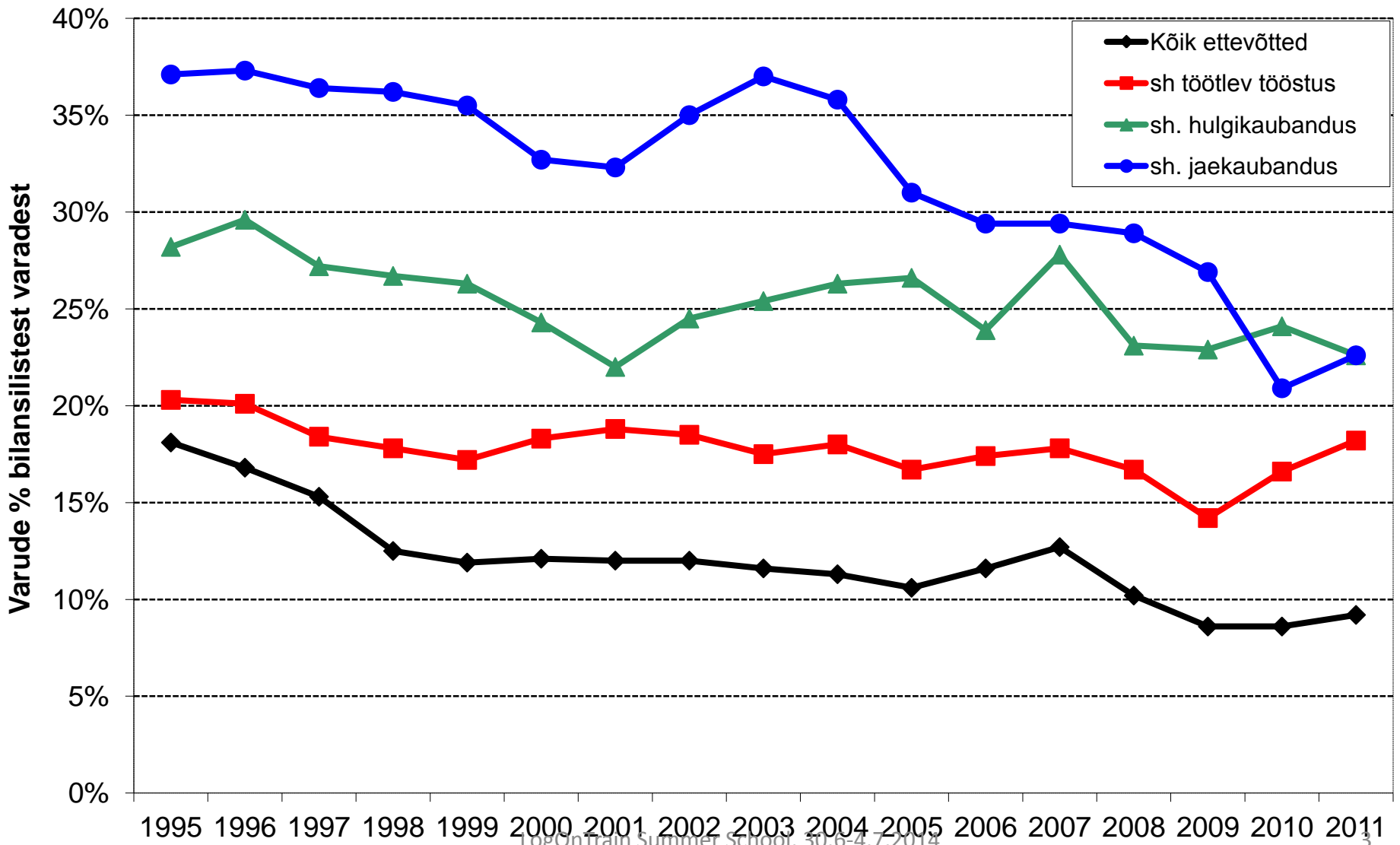
3. Inventory management – basic concepts

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Inventories

- In the supply chain one of the key variables which has to be managed is inventory. The inventory includes a vast spectrum of materials that is being transferred, stored, consumed, produced, packaged, or sold in one way or another during a firm's normal course of business.
- The planning, storing, moving and accounting for inventory is the basis for all logistics
- Inventory has a financial value, which for accounting purposes is considered a floating asset. However, it may be very difficult to convert physical inventory into liquid assets, hence the inventory is very risky investment
- Inventories represent the largest single investment in assets form many manufacturers, wholesalers and retailers. Inventory investment represents over 20% of the total assets of manufacturers and more than 50% of the total assets of wholesalers and retailers
- Thus one goal in operations is to keep the level of inventory in the supply chain as to low as possible thus freeing up funds for other purposes.
- Holding the inventories is connected with significant costs. Despite the all efforts and technological innovations, inventories are often still the asset with lowest return in the company. Arguably majority of companies hold 25-40% more inventories than actually needed. Unreasonably high inventory levels lower the company's profit and return of assets.

Varude (tooraine+lõpetamata toodang+valmistoodang+müügiks ostetud kaubad+ettemaksed hankijatele) osakaal Eesti ettevõtete aktivest 1995-2010, aasta lõpu seisuga.



Reasons for Inventories

- **Improve customer service**
 - Provides immediacy in product availability
- **Encourage production, purchase, and transportation economies**
 - Allows for long production runs
 - Takes advantage of price-quantity discounts
 - Allows for transport economies from larger shipment sizes
- **Act as a hedge against price changes**
 - Allows purchasing to take place under most favorable price terms
- **Protect against uncertainties in demand and lead times**
 - Provides a measure of safety to keep operations running when demand levels and lead times cannot be known for sure
- **Act as a hedge against contingencies**
 - Buffers against such events as strikes, fires, and disruptions in supply

Reasons Against Inventories

- They consume capital resources that might be put to better use elsewhere in the firm
- They too often mask quality problems that would more immediately be solved without their presence
- They divert management's attention away from careful planning and control of the supply and distribution channels by promoting an insular attitude about channel management

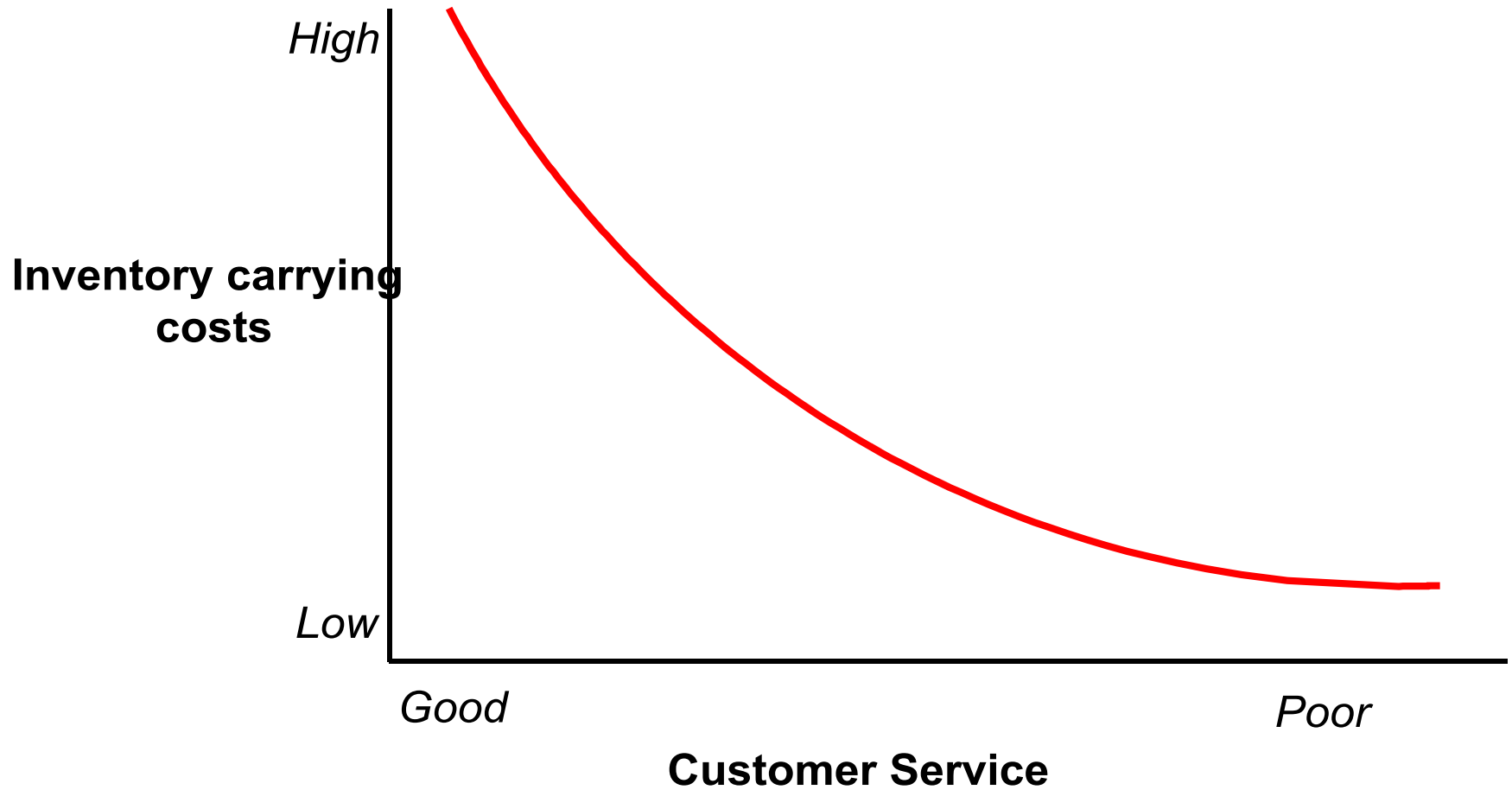
Main purpose of inventory management

Inventory management mean methods that are used for organizing, holding and replenishment of stock. The main goal – keep the inventories on optimal level, without stockouts and excesses. For this, two controversial but simultaneously mutually dependent tasks should be solved:

- **To have enough inventories to fulfill orders of outer and inner clients in a manner satisfying them.** Or with other words – assure high level of customer service. Usually this customer service level is measured as availability (fill rate).
- **To minimize inventory carrying costs,** first of all capital tied into inventories for maximizing the company`s profitability.

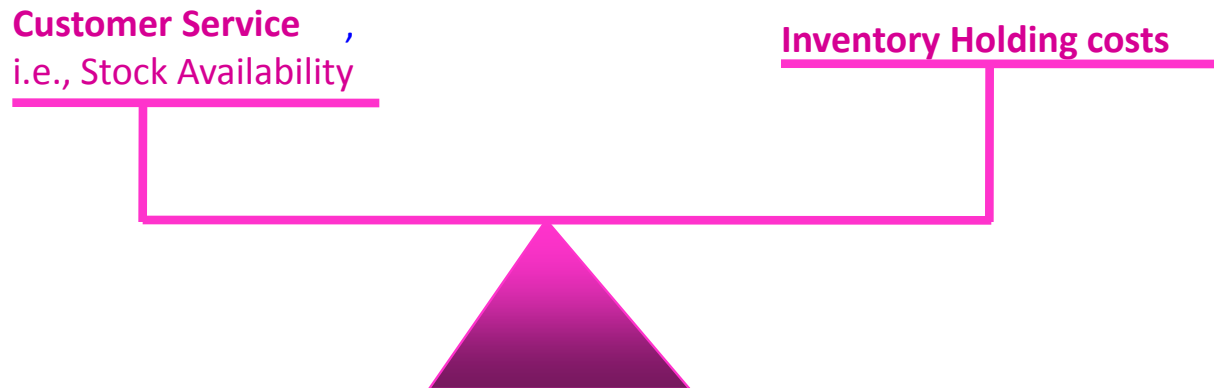
Trade-off should be found for achieving these two goals simultaneously.

The Trade-off between inventory carrying costs and customer service



Inventory Management Objectives

Good inventory management is a careful balancing act between stock availability and the cost of holding inventory.



- **Service objectives**

- Setting stocking levels so that there is only a specified probability of running out of stock

- **Cost objectives**

- Balancing conflicting costs to find the most economical replenishment quantities and timing

Effective inventory management

Effective inventory management is the result of outstanding inventory control and inventory management.

- **Inventory control** involves managing the inventory that is already in the warehouse, stockroom or store. That is knowing, what products are "out there", have much you have each item and where it is. It means having accurate , complete and timely inventory transactions record and **avoiding differences between accounting and real inventory levels**. Two tools commonly employed to ensure inventory accuracy and control are **ABC analysis** and **cycle counting**
- **Inventory management** involves determining, how to order products and how much to order as well as identifying the most effective source of supply for each item in each stocking location. Inventory management includes all activities of planning, forecasting and replenishment. **The main purpose of inventory management is minimization differences between customers demand and availability of items**. These differences have caused by three factors: customers demand fluctuations, suppliers delivery time fluctuations and inventory control accuracy

Inventory transactions

- Normal stock receipt – from previously issued purchase orders and transfers
- Unexpected stock receipts – the stuff that just shows up on receiving stock
- Requisitions – a request for material to be consumed within company
- Emergency requisitions
- Sales
 - Orders to be delivered
 - Orders to be picked up
 - Cash sales
 - Direct shipments
 - Orders for non-stock products
- Transfers to other warehouses or facilities
- Assembly orders
- Bin to bin transfers within warehouse
- Returns of stock material
- Returns of non stock material
- Returns of damaged material
- Returns to supplier
- Adjustments of on-hand quantities – who is allowed to approve adjustments?
Under what circumstances?
- Scrapping and writing-off stock

Types of inventories 1

By the position in company`s production/operation process:

- ❖ raw materials
- ❖ works-in-process
- ❖ finished goods

By Estonian financial accounting rules:

- ❖ raw materials
- ❖ works-in-process
- ❖ finished goods
- ❖ goods purchased for resale
- ❖ advance payments to suppliers

Types of inventories 2

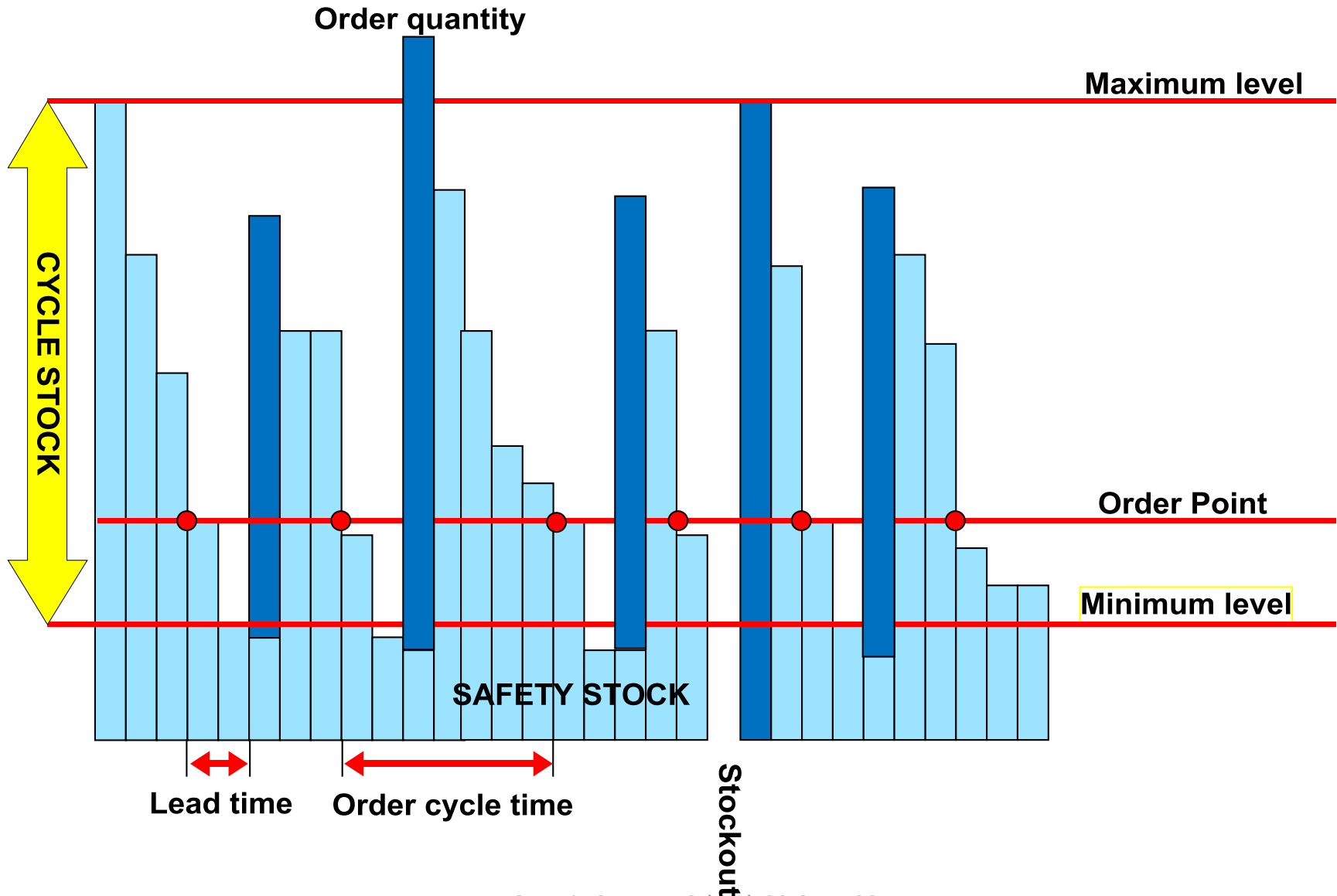
- **Cycle stock** – inventories for satisfying usual (predicted) demand between replenishments (receiving new ordered quantities)
- **In-transit inventories / pipeline stock** – items that are en route from one location to another. They may be considered part of cycle stock even they are not available for sale or shipment until after they arrive at the destination.
- **Safety or buffer stock** – held in excess of cycle stock because of uncertainty in demand or lead time. Amount depends on extent of demand fluctuation, replenishment lead time and planned availability level for customers. Makes the majority of inventory in the typical logistic system
- **Speculative stock** – held some reasons other than satisfying current demand (getting quantity discounts, forecasted purchase price increase or materials shortage, protecting against strikes/natural disasters etc. Production economies may also lead to the manufacture of products at times other than when they are in demand.
- **Seasonal stock** – form of speculative stock that involves accumulation of inventory before a seasonal period begins (or ends – in agriculture)
- **Dead stock** - items for which no demand has been registered for some specified period of time (obsolete products, demand season ended, etc).

Stock-keeping unit /item

The inventory control is made by a **stock-keeping unit**. SKU is an individual product that differs from other product some way. The difference could be in size, color, brand, model, package, function or some other relevant characteristic or combination of these. Each SKU has its own unique identification code (product code) in inventory accounting system and it is counted and stored separately from other items

Much of inventory control is directed at controlling each SKU in inventory. Although daily operations of inventories may require SKU level control, strategic planning of inventory levels can be accomplished by substantially aggregating product into broad groups by some characteristic – **product groups**. This is approach , when managing the inventory investment of all SKU-s collectively is the issue.

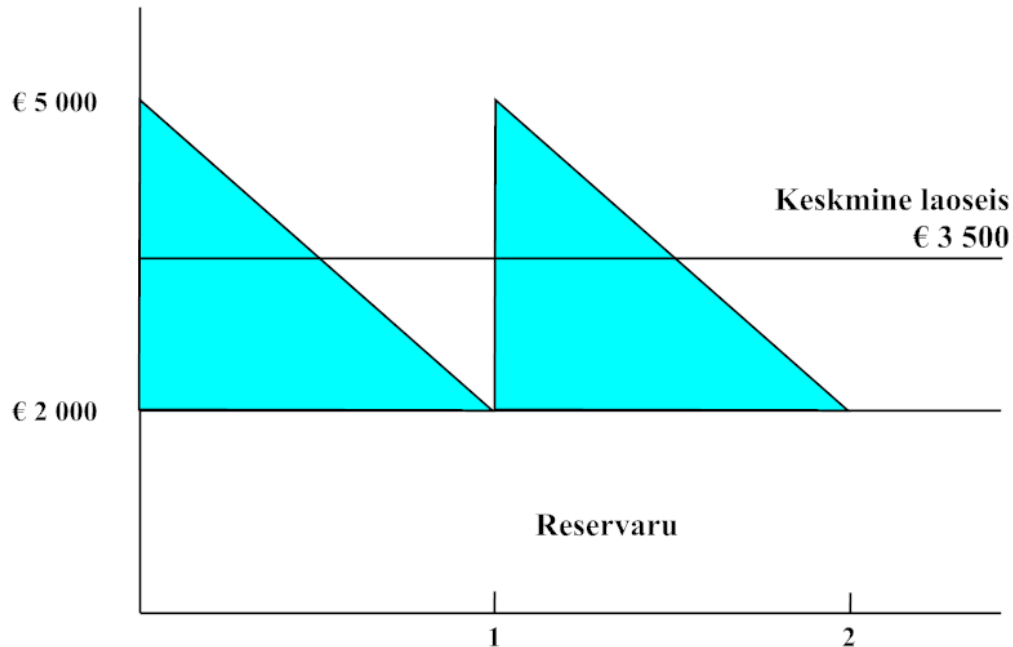
Inventory cycle



Three possible responses to stock-out

- **Backordering** – the quantity requested by the customer is placed on a separate order called a backorder and the special order is filled as soon as the product is available from internal or external source. In some cases the backorder is shipped directly from its original source to the customer
- **Substitution** – occur when a product acceptable for the customer is substituted for the product that is not available.
- **Lost sales** – occurs when unsatisfied client annuls the order. Common in retail situations

Average inventory



Allikas: Bowersox, Closs, Cooper. Supply Chain Logistics Management. McGraw - Hill, 2002. p. 287

The **average quantity or value of whole stock or quantity**. The given SKU is in warehouse at max level value € 5000 and at min level value € 2000. The difference between these two levels € 3000 (5000-2000) is the order quantity resulting in cycle inventory of € 1500. At the beginning of cycle stock level is at max. Customers deplete inventory when it reaches its min level. **Average inventory is therefore**

$$\frac{\text{max level} + \text{min level}}{2}$$

or ½ of replenishment order

As SKU stock is a sum of cycle and safety stock, the average inventory is:

½ replenishment order + safety stock

Inventory replenishment

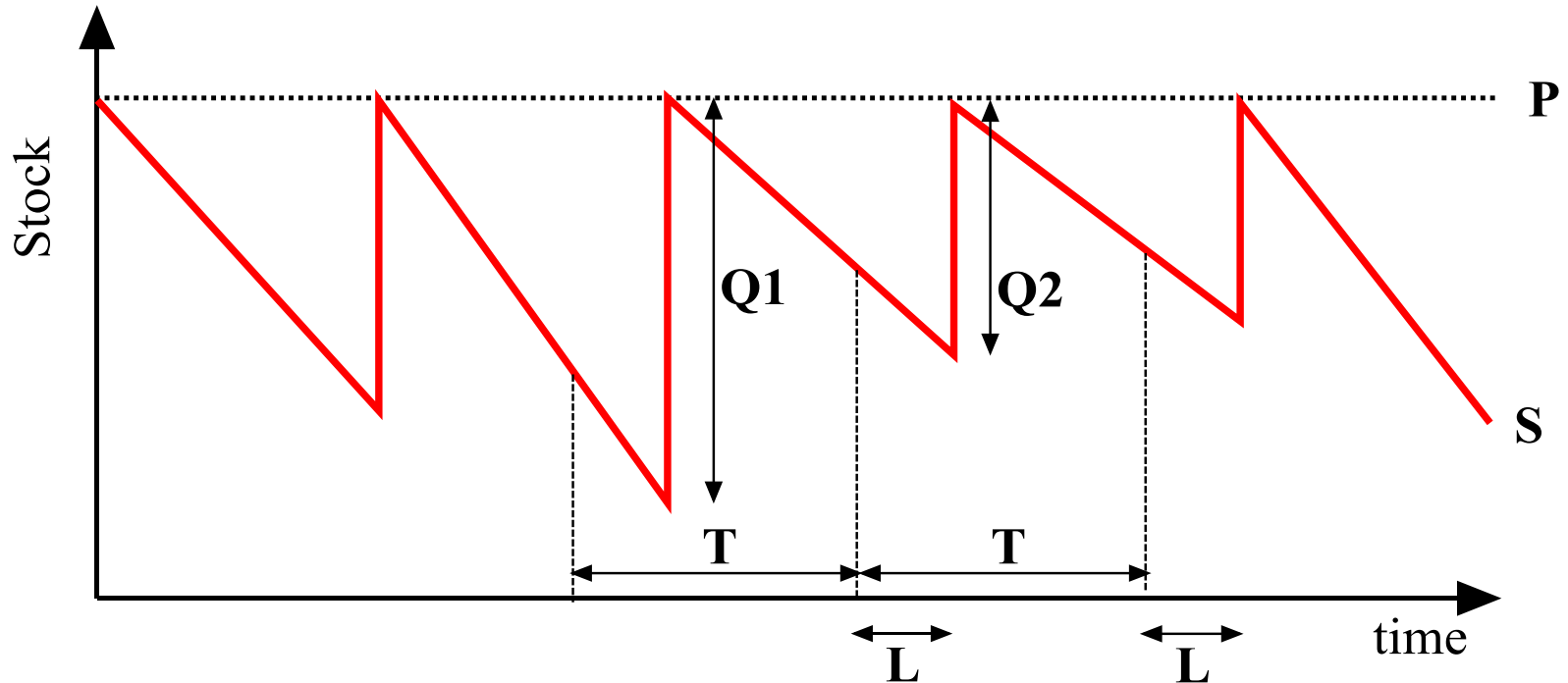
The aim of inventory replenishment is to ensure that the level of each SKU is kept at a level, optimal for established customer service level (availability). Inventory replenishment means answering the following questions :

- **What is the demand?**
- **What is currently available for satisfying demand?**
- **What is on order (but not received yet)?**
- **What will need to be ordered?**
- **When will orders need to be released?**
- **How much should be ordered?**

Majority of inventory replenishment methods are the variations of following three theoretical basic models:

- **Periodic review system or fixed interval system**
- **Reorder point system**
- **Time based order point system**

Periodic review system



S- stock level

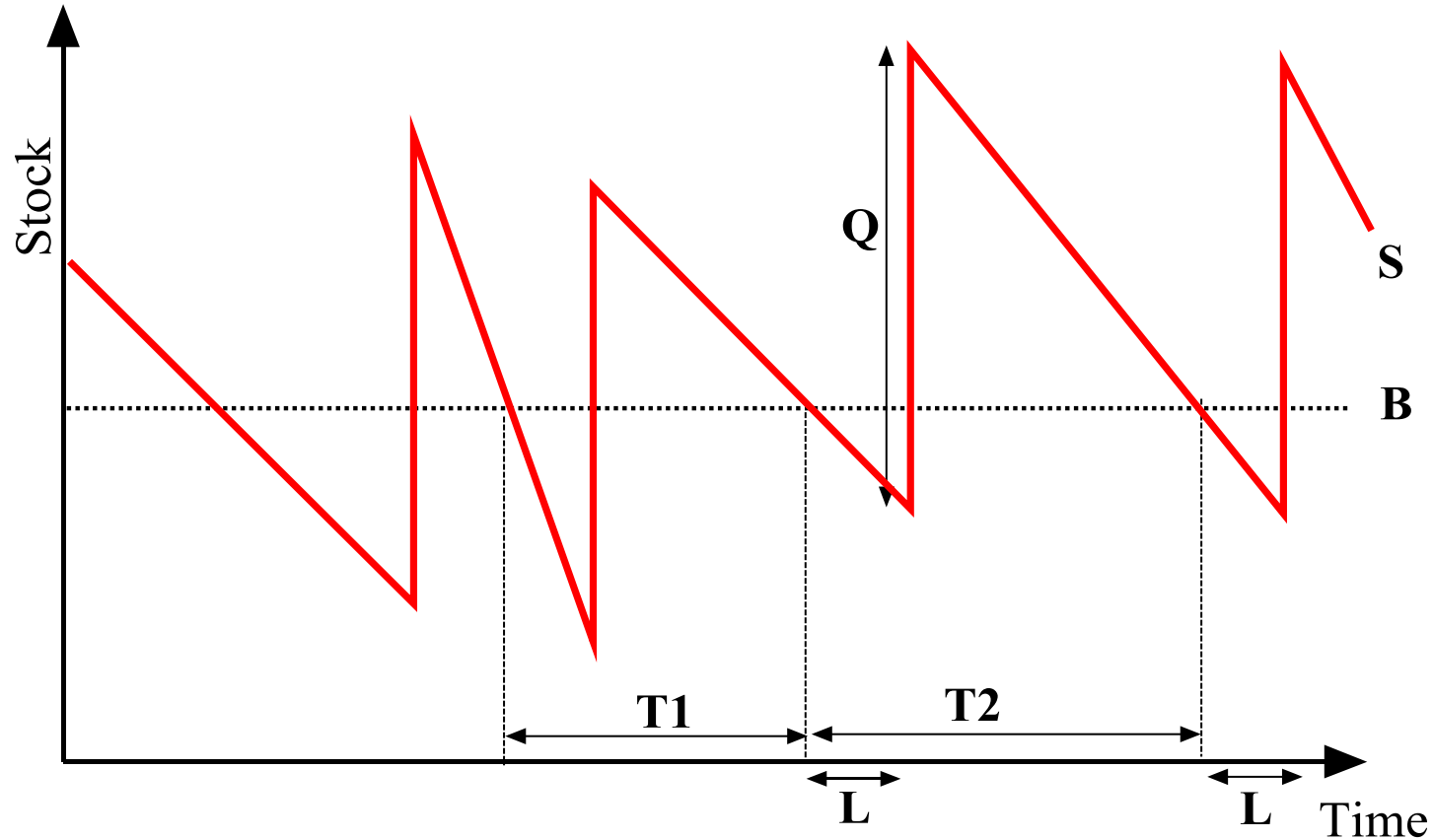
P- predetermined stock level

T- reorder cycle time or review period (constant)

L-lead time (assumed constant)

Q- quantity ordered (varies)

Reorder point system



S- stock level

B- fixed point reorder level

T- order cycle time (varies)

L- lead time (assumed constant)

Q- quantity ordered (constant)

Order Cycle Time

Interval between orders

$$T = \frac{Q}{D}$$

T= Order cycle time

Q= Order quantity

D= Assumed yearly demand

Example: yearly demand is 5000 Units and order quantity 60 units., then

$$T = \frac{60}{5000} = 0,012 \text{ years, or } 0,012 \times 52 = 0,6 \text{ weeks, or } 0,012 \times 365 = \sim 4 \text{ days}$$

Order point *versus* periodic review systems

	Order point	Periodic review
Maintenance expense		X
Ordering by item family		X
Lower inventory investment	X	
Replenishment predictability		X
Overall control	X	
Fast moving items	X	
Slow moving items		X
Higher customer service	X	
Computerization	X	
Lower purchasing costs		X

Time phased order point system

- TPOP is computerized management tool that plans inventory needs in priority sequenced, time phased manner to meet customers and forecast demand as it occurs.
- This technique is at the heart of MRP and DRP systems used for the control manufacturing and distribution channel inventories.
- Main advantage – inventory actions are triggered by matching supply with anticipated demand as it occurs in time. At the point where demand exceeds the supply, the system will alert inventory planner to order the item according to predetermined lot size and to have it available at the anticipated date on which stock-out will occur.
- In addition, each time when TPOP is generated, the system will resequence demand and supply relationships and suggest a new set of required order actions for the order planner

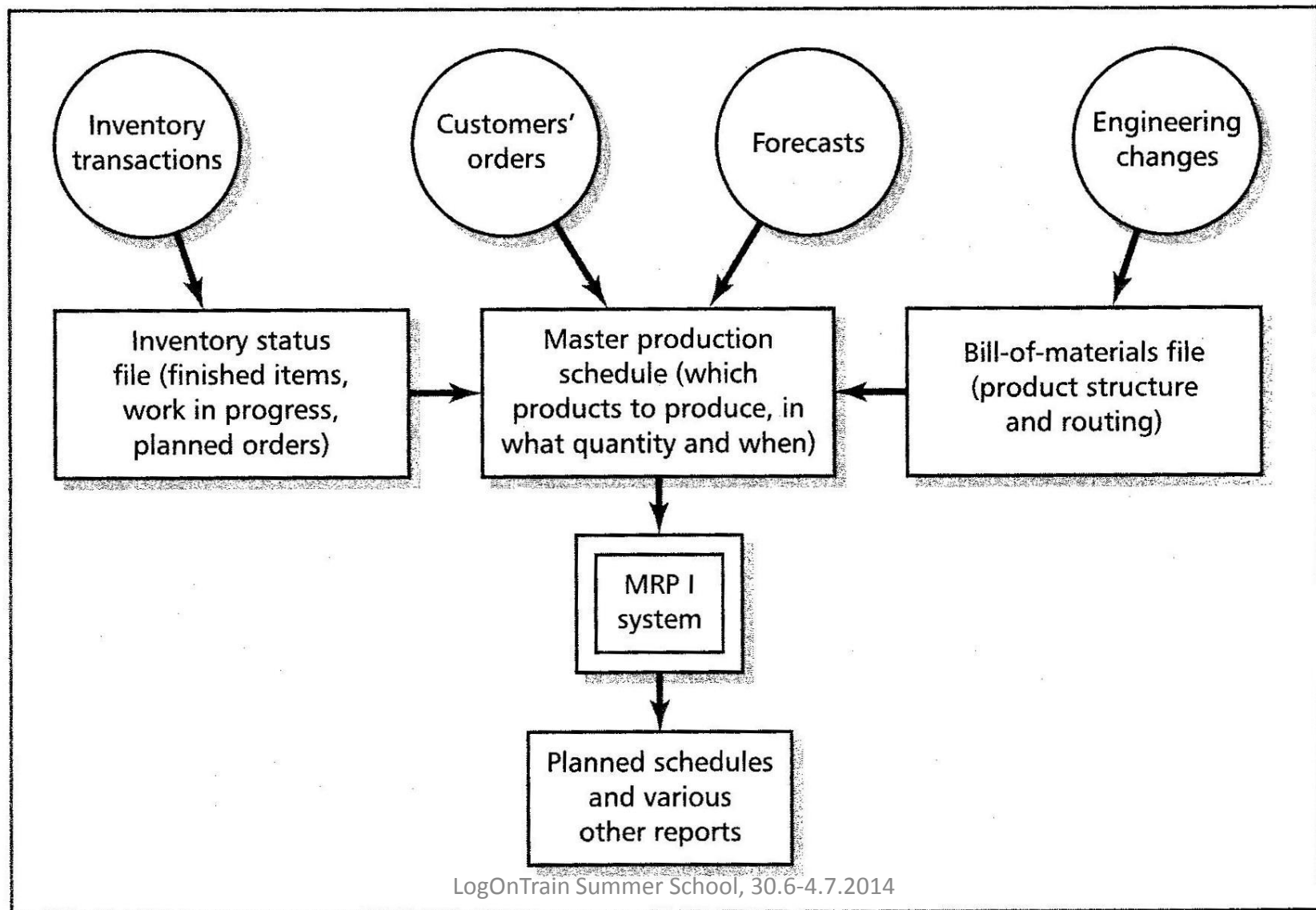
MRP- material requirements planning

Principle – if it is known what final product should be produced, it is also known how much materials, and components are needed for manufacturing this product. Theoretically there is no need for safety stock of materials, if the quantity of finished products and production schedule is known, then received inputs will be immediately used. The timing of incoming material flows according to production schedule is basis of MRP. MRP links procurement operations with manufacturing or material management functions.

MRP indicates:

- The types of material and the quantity that has to be purchased from outside, taking into account current inventory levels
- The types of materials that need to be manufactured internally and in what quantity, taking into account current inventory levels
- At what time to place these orders, either by purchasing outside or for manufacturing inside.

MRP components



MRP components 2

- **Master production schedule.** List of the products and services to be supplied within a specific period of time. This period must be sufficiently long to allow for the ordering and delivery of required sub-assemblies and parts, as well as allowing sufficient time for manufacturing the product in question. May be made up of forecast demand and actual known demand. It also lists the required outputs for the system and when the goods and services are required through the use of due date.
- **Bill of materials.** Diagram, engineering drawing or a listing of all materials and materials at various level. The product structure is often presented in a hierarchy form, where the end product would be at the highest level (level 0 or 1) and then components that go into making this product are at a lower level.
- **Inventory status file.** Complete record of the quantity of each material held in inventory. Detailed file would show transactions, receipts, disbursements, scrapped materials, planned orders, order releases, projections of delivery dates, quantities of each material to order, and when to place orders. Also would be the lead times, or the time required to produce a production lot in-house or receive a lot purchased from supplier. To take into account the lead time, a requirement in one time period will necessitate the release of the order in some earlier period according to the established delay or lead time.

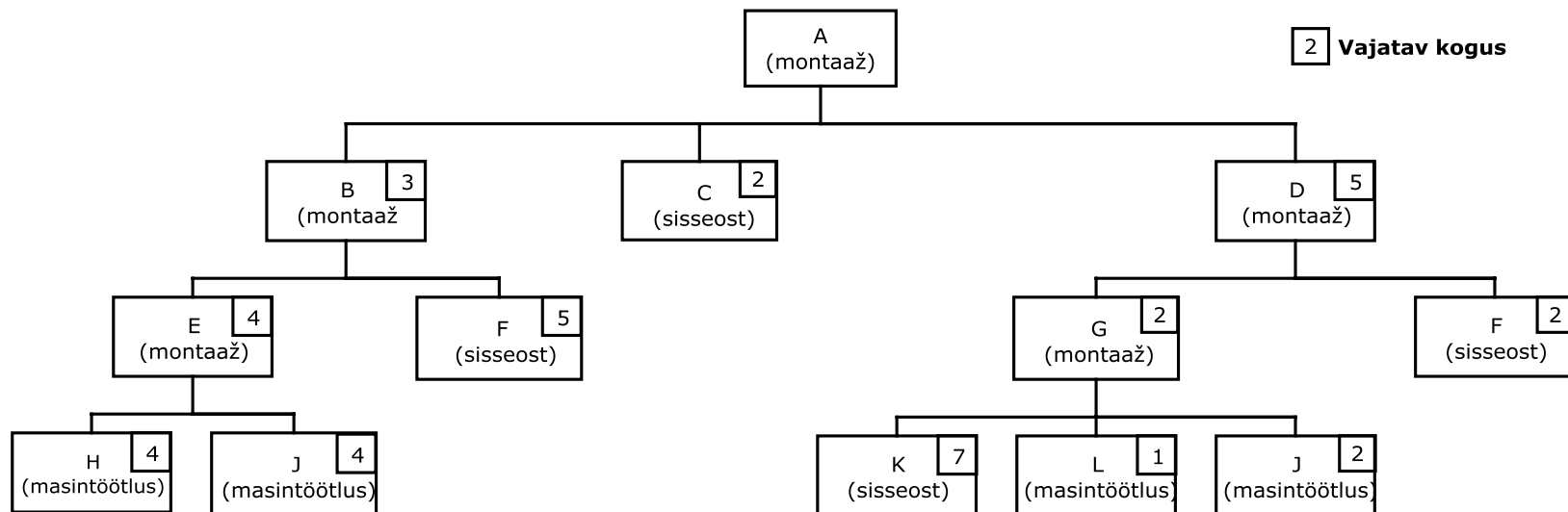
Bill of materials

Tasand 0

Tasand 1

Tasand 2

Tasand 3



Output of MRP

- A list of purchase requirements , which will list what needs to be purchased and when
- A manufacturing schedule, which will list what will be made and when it will be made
- The closing stock of parts, components and sub-assemblies after the master schedule has been completed
- The closing capacity available after the master schedule has been completed.
- A list of anticipated shortfalls in production – these may be due to shortages of parts of capacity.

Order point systems *versus* MRP systems

	Tellimispunkti süsteem	MRP süsteem
Demand	Independent	Dependent
Ordering philosophy	Replenishment	Needs
Forecasting	Basing on demand in the past	Basing on master schedule
Control princilpe	ABC grouping	All items are equally important
Purpose	Satisfaction of customers needs	Satisfaction of production needs
Order size determination	EOQ	Concrete request for concrete items
Design pattern	Unvaried	Changing but predictable
Inventory type	Finished products, spare parts	Works-in-process, raw materials

Min-max replenishment system

- The most popular replenishment method
- Variant of reorder point model with 2 differences
 - If SKU inventory level reaches reorder point or below it, the variable size order is made to rise inventory level onto predetermined maximum level (which is $EOQ + ROP$).
 - If the inventory level of some SKU has dropped to reorder point or below it, the inventory levels purchased from the same supplier are reviewed, despite these are above their reorder points. Beside ROP, each SKU has predetermined minimal order quantity. Replenishment orders for SKU-s, which need replenishing in quantities above the minimal size (but have not reached ROP) are added to order submitted to given supplier. So this approach enables joint ordering, therefore decreasing number of submitted orders and increasing order sizes

Min-max replenishment system principle -example

	Item 1, units	Item 2, units
ROP	100	200
EOQ	500	700
Max stock level (EOQ+ROP)	600	900
Min order size (1/2 of EOQ)	250	350
Stock at a moment	100	500

The stock level of Item 1 has dropped reorder point. Also the level of item 2, ordered from the same supplier as item 1, is reviewed. The difference between the max and current level of item 2 is $900 - 500 = 400$ units. As the difference 400 units exceeds the predetermined min order size for item 2 (350 units), replenishment order for item 2 is also placed in addition to order for item 1.

Product total cost

The objective of most companies is buy every item at the lowest total cost per unit. The total cost is the sum of three elements:

- ***Material cost (landed cost)***. the purchase price of product plus freight and any other charges that are related to specific shipment. Or manufacturing cost in production.
- **Ordering cost**. Cost of issuing, receiving and paying on a vendor. These are costs associated ordering frequency, not with quantity ordered
- ***Inventory carrying or holding cost***. Cost of maintaining inventory in warehouse before it is sold, transferred or otherwise used. These are costs associated with quantity ordered, not with ordering frequency.

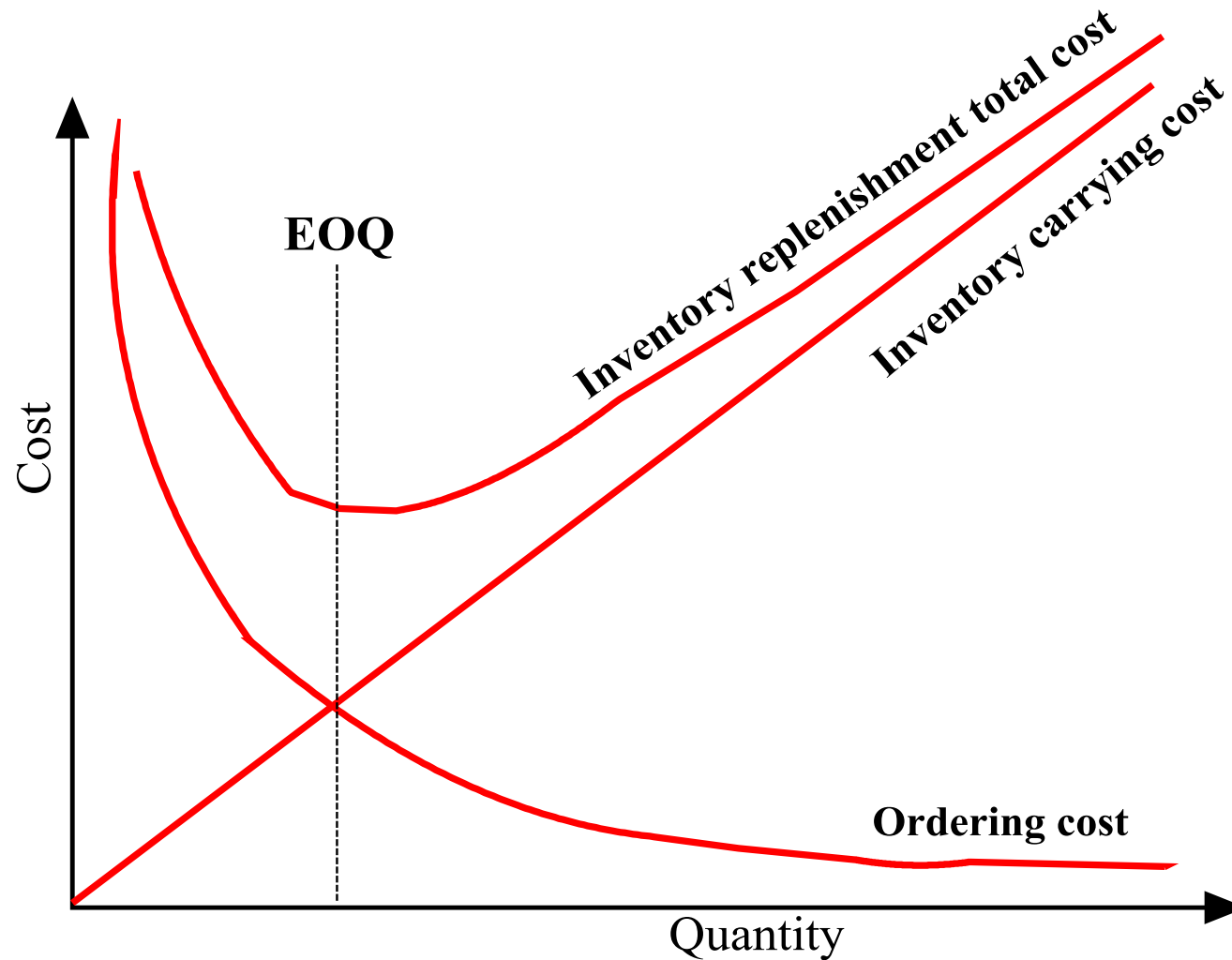
Out of stock costs

One additional cost element related to inventories – cost incurred, when an order is placed but cannot be filled from inventory from which the order is normally assigned. Finding these cost is quite complicated and inaccurate

There are two kinds of out of stock costs:

- **Lost sales cost** – when customer faced with an out of stock situation, chooses to withdraw request for product. Unearned profit from given sale + possible negative effects on future sales.
- **Back order cost** – when customer decides to wait in out of stock situation. The sale is not lost, only delayed, but it incurs backorder processing costs and additional transportation and handling costs (if backorder is processed and delivered as separate shipment).

Economic order quantity



Economic order quantity 2

Formula was created in 1913, named also Wilson formula by creator.

S= ordering cost (€ / order).

D= Yearly demand (units)

C= Inventory carrying per year, expressed as percentage or coefficient of average stock value (e.g. 25% or 0,25)

V= landed cost per unit (purchase price + freight & other charges for receiving shipment)

Q= quantity per order (units / order).

$$EOQ = \sqrt{\frac{2DS}{CV}}$$

Example $V = € 50/tk$; $C = 25\%$, $S = € 5$, $D = 5000 tk$. Therefore:

$$EOQ = \sqrt{\frac{2 * 5 * 5000}{0,25 * 50}} = \sqrt{\frac{50000}{12,5}} = \sqrt{4000} = \sim 63 tk$$

Usability of EOQ

- Formula is used for calculating optimal production batches: as "lot size" formula and S is setup cost and V is manufacturing cost
- While EOQ may not apply to every inventory situation, most organizations will find it beneficial in at least some aspect of their operation. Anytime if having repetitive purchasing or planning of an item, EOQ should be considered.
- Obvious applications for EOQ are purchase-to-stock distributors and make-to-stock manufacturers, however, make-to-order manufacturers should also consider EOQ when they have multiple orders or release dates for the same items and when planning components and sub-assemblies.
- Repetitive buy maintenance, repair, and operating (MRO) inventory is also a good application for EOQ.
- Though EOQ is generally recommended in operations where demand is relatively steady, items with demand variability such as seasonality can still use the model by going to shorter time periods for the EOQ calculation.

Total Stocking Cost formula (TSC)

EOQ-formula is derived from Total Stocking cost formula (TSC), which summarizes ordering and carrying costs of a product

$$TSC = \frac{QCV}{2} + \frac{DS}{Q}$$

First half of equation calculates inventory carrying cost and second ordering cost.

- Average inventory is $\frac{1}{2}$ of the sum of max and min inventory level = $Q : 2$.
- Annual inventory carrying cost is average inventory multiplied by inventory carrying cost percentage and by stock unit value = $(Q : 2) \times C \times V$.
- Number of purchase orders made annually = annual demand D divided by order quantity $Q = D : Q$
- Ordering cost = annual purchase orders multiplied by cost per order $(D : Q) \times S$.

Total Product Costs formula (TPC)

Total Stocking Cost formula is a part of Total Product Cost Formula, which summarizes total replenishment cost and purchase cost in time period.

$$TPC = TSC + DP, \text{ ehk } TCP = \frac{QCV}{2} + \frac{DS}{Q} + DP$$

P = price of product

TSC/TPC is theoretical formula assuming that demand and lead time are constant and do not account costs associated with safety stock and inventories in transit.

EOQ applicability in practice - theoretical assumptions of formula

- A continuous, constant and known rate of demand
- Constant and known replenishment or lead time
- Constant purchase price independent of the order quantity on time
- Constant transportation cost independent of the order quantity of time
- The satisfaction of all demand (no stock-outs are permitted – no need for safety stock)
- No inventory in transit
- Only one product in inventory or at least no interaction between products (independent demand items).
- An infinite planning horizon
- No limit on capital availability

EOQ applicability in practice – order quantity elasticity to TSC

From other side- Order quantity can be varied in large extent without significant changes in total stocking cost.

For example, EOQ is 63 units, then TSC is € 790,58 in year.

If we would like to make order quantity of 50 units (21% less than calculated EOQ), then we will get TSC € 812,5 in year (2,8% higher than in case of EOQ).

If we would like to make order quantity of 80 units (27% more than calculated EOQ), TSC will be again € 812,5 or only 2,8% higher.

Order quantity, units	Orders per year, D/Q	Ordering cost (€), $S^*(D/Q)$	Carrying cost (€), $(1/2Q * C * V)$	TSC per year (€)
10	500	2 500,00	62,50	2 562,50
20	250	1 250,00	125,00	1 375,00
30	167	833,33	187,50	1 020,83
40	125	625,00	250,00	875,00
50	100	500,00	312,50	812,50
60	83	416,67	375,00	791,67
63	79	396,83	393,75	790,58
70	71	357,14	437,50	794,64
80	63	312,50	500,00	812,50
90	56	277,78	562,50	840,28
100	50	250,00	625,00	875,00
110	45	222,27	687,50	914,77
120	42	208,33	750,00	958,33
150	33	166,67	937,50	1 104,17
200	25	125,00	1 250,00	1 375,00
250	20	100,00	1 562,50	1 662,50

EOQ extensions

- In addition to basic EOQ model, there are various extensions of basic formula, which take into account different additional variables or combinations of variables (simultaneous supply and usage, quantity discounts, transport rates dependency on order quantity, variation of demand and lead times, in production order quantities dependency on lot size, ordering several items, taking into account capital availability etc.
- All software for conventional inventory management are basing on EOQ and its extensions.

EOQ input data

- While the calculation itself is fairly simple, the task of determining the correct data inputs to accurately represent firm`s inventory and operation is more complicated.
- Exaggerated order costs and carrying costs are common mistakes made in EOQ calculations.
- Using all costs associated with firm`s purchasing and receiving departments to calculate order cost or using all costs associated with storage and material handling to calculate carrying cost will give highly inflated costs resulting in inaccurate results from EOQ calculation.

Ordering cost - components

Sum of the fixed costs that are incurred each time an item is ordered. These costs are not associated with the quantity ordered but primarily with physical activities required to process the order. This includes:

- Deciding, what products need to be replenished
- Issuing the purchase order
- Expediting the purchase order, if necessary (securing the quality and timely delivery of goods and components).
- Processing the receiving paperwork for shipment
- Approving the supplier`s invoice for payment
- Processing the supplier`s payment

For the most part, ordering cost is primarily the labour associated with processing the order.

What is and what is not going into ordering cost?

Purchasing department

Working time included to ordering cost	Working time not included to ordering cost
<ul style="list-style-type: none">• creating the PO-s and approval steps• contacting to suppliers• expediting (securing the quality and timely delivery of goods and components)• dealing with supplier invoices	<ul style="list-style-type: none">• reviewing forecasts• sourcing (finding, evaluating and engaging suppliers)• getting quotes (unless company get quotes each time when ordering)• preparation for procurement of new items

Warehouse

<ul style="list-style-type: none">• checking and entering receipts documentation, doing any other related paperwork	<ul style="list-style-type: none">• repacking materials, unloading trucks, delivery to other departments
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It is usually the most effective to determine the percentage of time within the department consumed performing the specific activities and multiplying this by the labour cost for a certain period.

Ordering cost is calculated per order or order line, dividing annual ordering cost by orders or order lines issued annually. The typical ordering costs per order line in USA are within 5-6 US dollars.

Ordering cost in manufacturing

The ordering cost would include:

- time to initiate the work order
- time associated with picking and issuing components
- all production scheduling time
- machine setup time
- inspection time

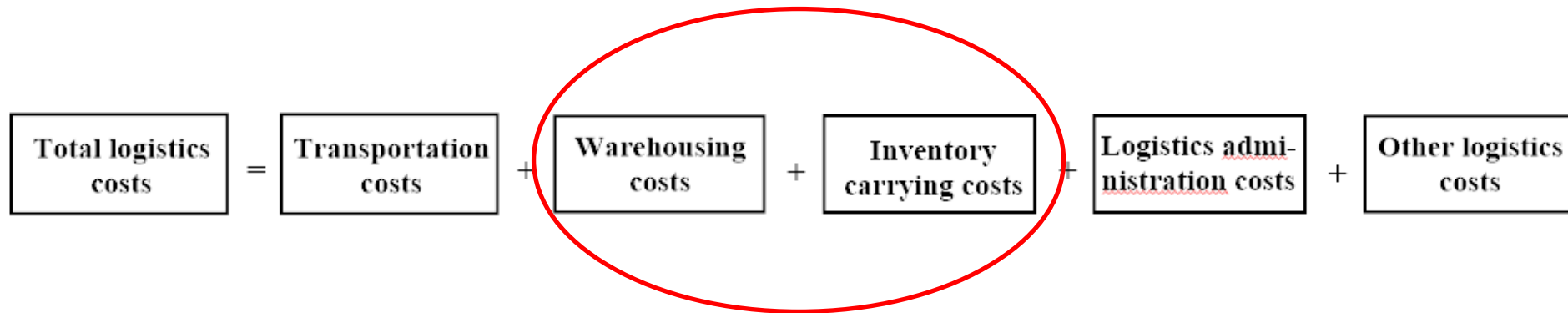
Inventory carrying cost (ICC)

Cost associated with having inventory in hand

Term "Inventory carrying cost" may be used in two different contexts.

- **Determining firm's total logistics cost (TLC)**
- **Calculating EOQ for SKU**

ICC in TLC context



Warehousing costs

Costs of keeping/using the warehouses. The accounting of warehousing costs depend on storage solutions used – private & rented warehouse or using public warehouses.

Warehousing costs should be separated into two distinct categories:
throughput related and storage related.

1. Throughput costs are the costs which do not directly depend on inventory levels. For private & rented warehouses these are primarily fixed and take the form of step function (if the space rented or number of operated warehouses changes) Such costs are: labour, communal costs (heating, electricity etc.), depreciation or rent of building and equipment.

If buying public warehouse services, warehousing costs include goods handling, picking, packing, sorting, labelling and other handling fees invoiced by public warehouse keeper

2. Storage costs. These costs change with the level of inventory held in warehouse and should be included in inventory carrying costs. These tend to be negligible for private & rented warehouses. If buying public warehouse services, storage costs include storage fees invoiced by public warehouse keeper, directly associating with quantity of goods, stored in public warehouse during certain period (e.g. month).

Inventory carrying costs – total cost approach

The methodology of accounting inventory was worked out only in 1978. These include the following elements:

- **Capital cost.** Opportunity cost of money tied in firm's inventory. This may represent over 90% of total inventory carrying cost. This cost is quite subjective because depends on the interest rate used for calculating opportunity cost. This interest rate can be based on:
 - **WACC** (weighted average capital cost) – considered most objective for realistic cost overview
 - **Hurdle rate** – minimal acceptable return on investment, accepted by company
 - **The lowest bank loan interest rate** (currently around 5-6%) – still most widespread in practice
- **Inventory service costs** – insurance and taxes on inventory
- **Storage costs** – part of warehousing costs depending on inventory level
- **Inventory risk costs** – obsolescence, damage, pilferage, and relocation costs

Structure of inventory carrying cost- example

Capital cost	82,00%
Service cost (taxes 0,5% and insurance 0,25%)	0,75%
Storage cost	3,25%
Inventory risk costs	14,0%
TOTAL	100,00%

Allikas: Ballou, R. H. Business Logistics / Supply Chain Management. 5th Ed. Pearson Education 2004, p. 339

Inventory carrying cost – approach for calculating EOQ

- **Inventory capital costs** and **inventory service cost** – no difference from total cost approach
- **Inventory risk costs** (obsolescence, damage, pilferage, and relocation) – should be included in EOQ calculation only when these are direct result of inventory levels and are significant enough to change the result of EOQ equation.
- **Storage cost, if bought completely from public warehouse keeper** - no difference from total cost approach

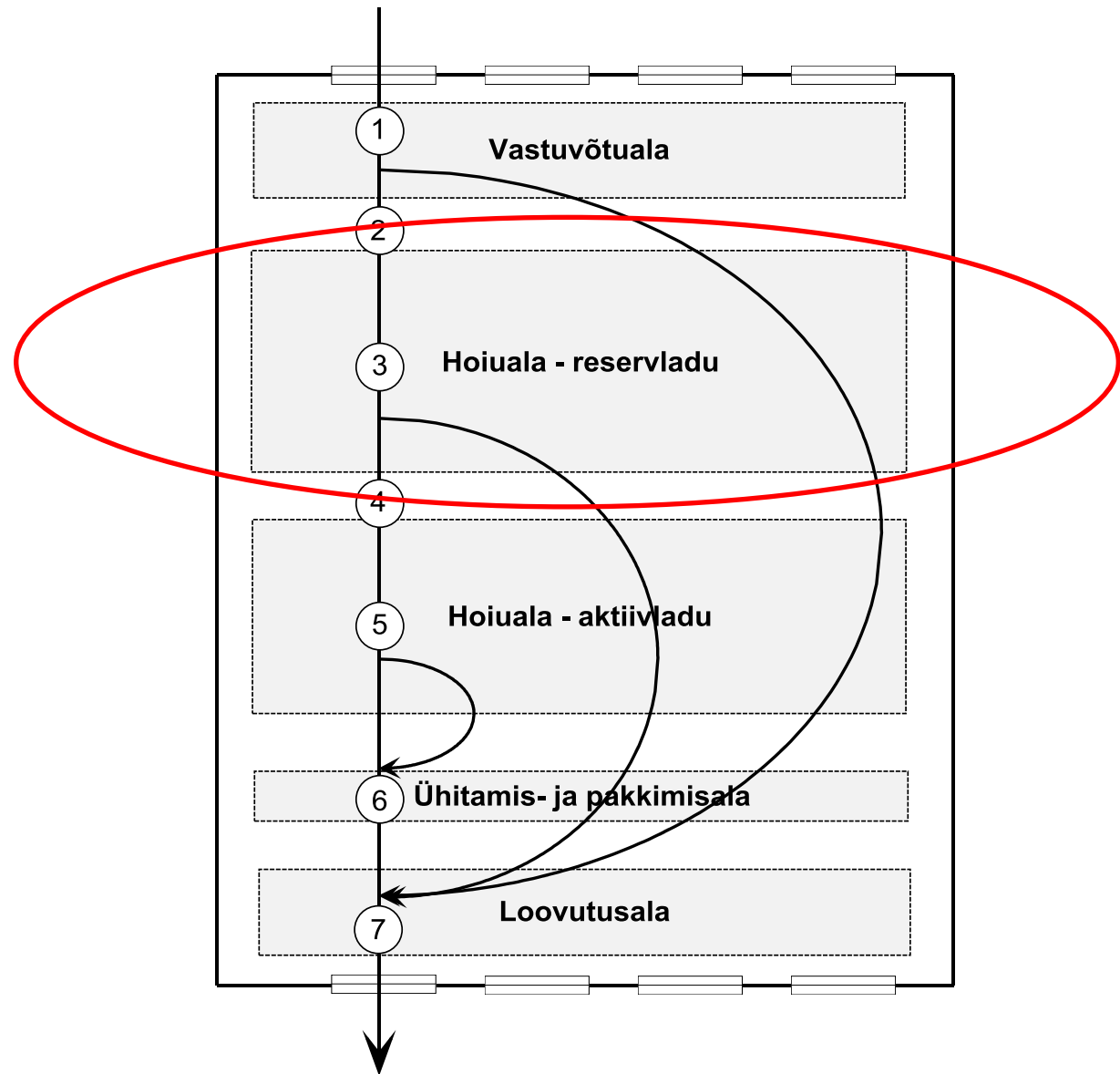
If company uses private or rented warehouse, mistakes in calculating storage cost are common in EOQ implementations. Generally companies include all costs associated with the warehouse. This tends to include costs that are not directly affected by the inventory levels and does not compensate for storage characteristics. Carrying costs for the purpose of the EOQ calculation should only include costs that are variable based upon inventory levels.

Determination of storage costs in using private & rented warehouse

- Storage area cost – proportional share of depreciation/rent and communal costs is included
- If there is picking area in warehouse (fixed picking locations not designed to hold entire inventory – this portion of warehouse **is not** included in storage cost
- Shipping, receiving and other working areas **are not** included
- If there is additional warehouse for overflow inventory – all areas of second inventory are included as well as freight and labour costs associated with moving the material between the warehouses.
- The costs of physical inventory and cycle counting are included

There are situations where any storage costs will not be included in EOQ calculation. If there is excess storage space of which it has no other uses it is reasonable not to include storage costs since reducing inventory does not provide any actual savings in storage costs.

In the case of private or rented warehouse only proportional share of depreciation/rent and communal costs is included in storage costs, not all warehouse costs!



Inventory carrying cost – approach for calculating EOQ - 2

- If total inventory carrying cost has found, this are divided by the average inventory investment /average stock value). Usually it is expressed as percentage.
- Principally it shows, how many cents cost of maintaining a euro worth of inventory in company for an entire year.
- Typical inventory carrying cost percentage values range between 18% and 28%

Reorder point

The triggering mechanism, that alerts inventory planners to that a stock-out is eminent is some form of order point. Whether it is derived using a mathematical model or rule of thumb, the order point provides the planner that must be acted on to avoid a stock-out. Order point attempts to estimate demand during the replenishment time to which is added a calculated safety stock to compensate for possible fluctuation in demand

$$ROP = d * LT + SS$$

ROP = reorder point

d = demand during the lead time

LT = average lead time

SS= safety stock

Example; average demand is 200 units per week. Average lead time is 2 weeks. Item's planned safety stock is 50 units.

$$ROP = 200 * 2 + 50 = 450tk$$

If item level drops to 450 units, new order should be made

Supplier delivery time *versus* replenishment lead time

In determining lead time for ROP should taken into account that replenishment lead time is not the same as supplier`s delivery time. The anticipated lead time for ROP is the sum of four factors:

- **The time it takes to place an order – time for determining the replenishment need, preparation of purchase order (including consolidation orders, if needed)and sending it to supplier**
- **The time it takes the supplier to process order and ship the material .**
- **The time it takes for the material to travel from the vendor to buyer`s warehouse (transit time).**
- **The time it takes to receive, unpack, and prepare the stock receipt for sale or use**

Supplier delivery time includes only second and third factor (transit time included when supplier arranges delivery) For maximum accuracy of replenishment lead time, all four listed factors should be carefully taken into account.

Inventory position

The replenishment decision is made, when a inventory position of item, not on-hand inventory reaches reorder point. The replenishment decision model includes the following components

- **On-hand inventory.** Quantity that inventory system shows as being physically in stock. This value should never negative. This is the starting point for the replenishment calculation
- **Available inventory** is found by subtracting from on hand inventory all order demand quantities, whether allocated or unallocated. The balance remaining is the quantity available to immediately satisfy new customer demands. This value can be negative, if open customer orders exceed on-hand inventory
- **On-order inventory** is replenishment stock that has been ordered but has not yet been received. Although the inventory position calculation considers on-order inventory as if it were on hand, this stock should not be allocated to open customer orders or existing backorders within the replenishment lead time
- **Inventory position** – value that is determined for given item by subtracting the inventory requirements generated by open customer and interbranch transfer orders, allocated (committed) and backorders from the total on-hand stock and expected on-order inventory.

Safety stock

Perhaps the most common buffer against uncertainty that companies use is safety inventory—carrying extra inventory just in case demand exceeds the forecast, just in case manufacturing has a break-down, and just in case a supplier delivery is late or short in quantity.

There are numerous methods for determining safety stock quantity , for example:

- **Certain percentage of forecasted demand.** E.g. If item's demand is 100 units per month and planned SS is 10% of demand, then SS is $100 \times 0,1 = 10$ units.
- **Fixed quantity** – SS is 15 units for every item
- **Sufficiency for covering demand during certain period** (stock cover, days of supply). E.g. If the demand for item is 100 units monthly and SS is planned to be 10 days sales, the SS should be $(10 \text{ days} \times 100 \text{ pcs}) : 30 \text{ days} = 34 \text{ pcs}$
- **Average difference between forecasted and real sales.** E.g. If the average sales forecast for last 3 months was 115 pcs/month and actual sales 100 pcs/month. Average difference is 15 pcs, which will be the planned SS quantity.

The more complicated methods are basing predominantly on statistical model of standard deviation of normal distribution of numbers to determine probability

Standard deviation

Standardhälbe arvutamine

Müük (tk)	$x-\lambda$	$(x-\lambda)^2$
20	5,4	29,2
14	-0,6	0,4
5	-9,6	92,2
27	12,4	153,8
16	1,4	2,0
11	-3,6	13,0
9	-5,6	31,4
8	-6,6	43,6
21	6,4	41,0
15	0,4	0,2
$\lambda=14,6$		$\sigma^2=40,6$
		$\sigma \approx 6,4$

Standard deviation shows the spread of distribution of numbers . It is calculated by the following steps.

- 1) Determine the mean (average) of a set of numbers.
- 2) Determine the difference of each number of the mean.
- 3) Square each difference.
- 4) Calculate the average of the squares.
- 5) Calculate the square root of the average.

Näide Arvutame toote A nõudluse standardhälbe 10 päeva müügistatistika baasil. Keskmiseks müügiks / nõudluseks (λ ehk lambda) ajaperioodil saame 14,6, hälvete ruutude keskmine on 40,6, viimasest ruutjuure võttes saame standardhälbeks 6,4 kaubaühikut. Praktikas on objektiivsuse huvides muidugi mõistlik arvutada standardhälve pikematele ajaperioodidele.

Alternative possibility for finding SD is insert function STDEVPA in Microsoft Excel or OpenOffice/LibreOffice Calc programs.

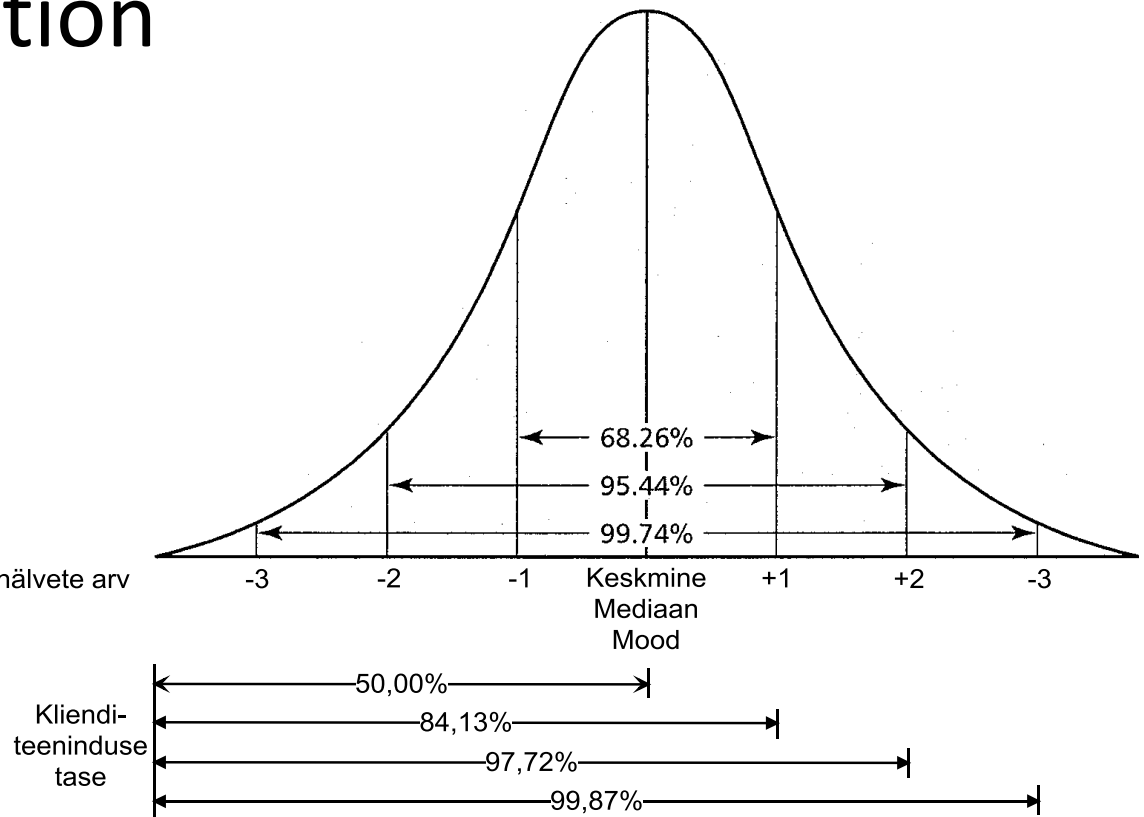
The basis of finding of SD can be:

- 1) demand variation during time period (average demand in period – each day sale)
- 2) The demand forecast differences from actual demand by months or weeks (actual demand – forecast).

Normal Distribution

Term used in statistical analysis to describe a distribution of numbers in which the probability of occurrence, if graphed, would follow the form of a bell shape curve. This is the most popular distribution model for determining probability and has been to work 'well in predicting demand variability based upon historical data.

Standardhälvete arv



The basic parameters of Normal distribution are the average value of value series and standard deviation. Normal distribution assumes that three measures: mean (average), median (middle) observation and the mode (most frequently observed) value are all the same. By theory, within ± 1 standard deviation, 68,26% of all events occur. Within ± 2 standard deviation 95,44% of all events occur. And within ± 3 standard deviation 99,74% of all events occur E.g. on the basis of example for calculating the standard deviation can be said, that:

68,3% of sales days the daily sales are $14,6 \pm 6,4$ or 8-21 items in day

95,5% of sales days the daily sales are $14,6 \pm 2 \cdot 6,4$ or 2-27 items in day

99,7% of sales days the daily sales are $14,6 \pm 3 \cdot 6,4$ or 0-34 items in day

Service factor

The probability that actual sale do not exceed the average sales more than certain number of standard deviations, can be looked as customer service level. For achieving this customer service level, the safety stock will be owned in extent of certain number of standard deviations. This value is referred as **service factor**.

The relationship between customer service level and probability, that stock-out will not occur or between the number of standard deviations and service factor is showed in the table in following slide. Alternative possibility for finding service factor from the customer service percentage is to use MS Excel function NORMSINV.

Finding the service factor from desired level of customer service

Customer service level	Service factor	Customer service level	Service factor
50,00%	0,00	90,00%	1,28
55,00%	0,13	91,00%	1,34
60,00%	0,25	92,00%	1,41
65,00%	0,39	93,00%	1,48
70,00%	0,52	94,00%	1,55
75,00%	0,67	95,00%	1,64
80,00%	0,84	96,00%	1,75
81,00%	0,88	97,00%	1,88
82,00%	0,92	98,00%	2,05
83,00%	0,95	99,00%	2,33
84,00%	0,99	99,50%	2,58
85,00%	1,04	99,60%	2,65
86,00%	1,08	99,70%	2,75
87,00%	1,13	99,80%	2,88
88,00%	1,17	99,90%	3,09
89,00%	1,23	99,99%	3,72

For example, when the average item`s sales are 14,6 units and standard deviation is 6,4 units, then customer service level 95% means need to hold safety stock:

1,64*6,4=~11 units

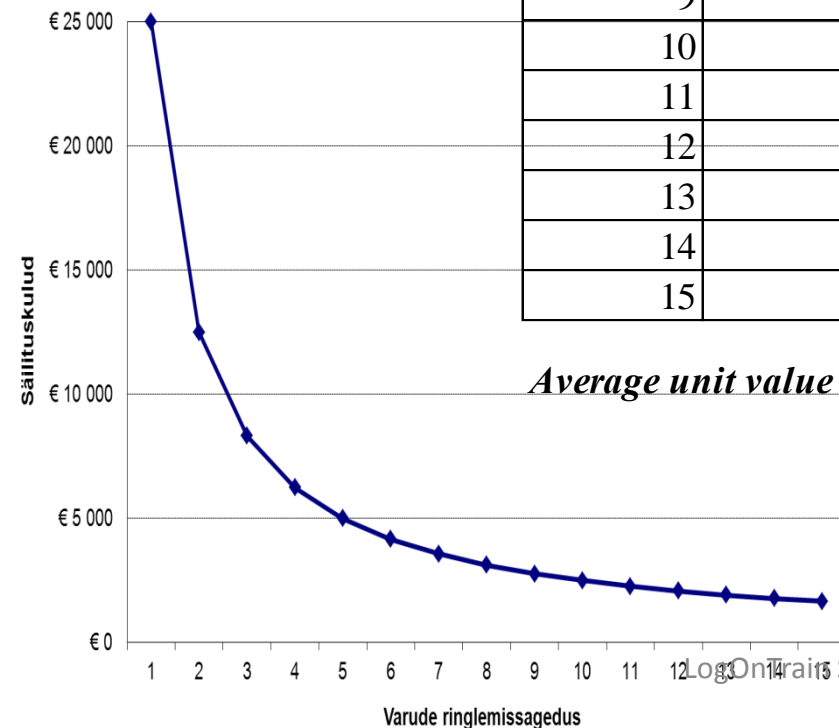
Inventory turnover

- Measures, how many times the stock hold by company changes within a year. With higher inventory turnover , company is using it`s assets more effectively and the inventory carrying cost per unit held in inventory is lower. Low turnover indicates the existence of excess, slow moving or obsolete inventories in stock. Often the turnover of raw materials, finished products and works-in-process is measured separately-
- **For finding inventory turnover the overall, product group or item sales from stock are divided by average overall, product group or item stock. This can be counted in units or in value (value of products according to landed or production cost, VAT is not included).**

The impact of inventory turnover on working capital and inventory carrying cost

Inventory turnover	Average inventory, €	Average inventory, units	Inventory carrying cost (25% of average stock value)	Saving in inventory carrying cost
1	€ 100 000	2 000	€ 25 000	
2	€ 50 000	1 000	€ 12 500	€ 12 500
3	€ 33 333	667	€ 8 333	€ 4 167
4	€ 25 000	500	€ 6 250	€ 2 083
5	€ 20 000	400	€ 5 000	€ 1 250
6	€ 16 667	333	€ 4 167	€ 833
7	€ 14 286	286	€ 3 571	€ 595
8	€ 12 500	250	€ 3 125	€ 446
9	€ 11 111	222	€ 2 778	€ 347
10	€ 10 000	200	€ 2 500	€ 278
11	€ 9 091	182	€ 2 273	€ 227
12	€ 8 333	167	€ 2 083	€ 189
13	€ 7 692	154	€ 1 923	€ 160
14	€ 7 143	143	€ 1 786	€ 137
15	€ 6 667	133	€ 1 667	€ 119

Average unit value - €50



Stock cover (days of supply)

The inverse figure for inventory turnover is stock cover. Stock cover shows, for how many days of sales or use the existing item's stock can be used.

$$\textit{Stock cover} = \frac{365}{\textit{inventory turnover}} \text{ or } \frac{\textit{existing stock}}{\textit{forecasted daily demand or use}}$$