LOGISTICS: METHODS AND MODELS

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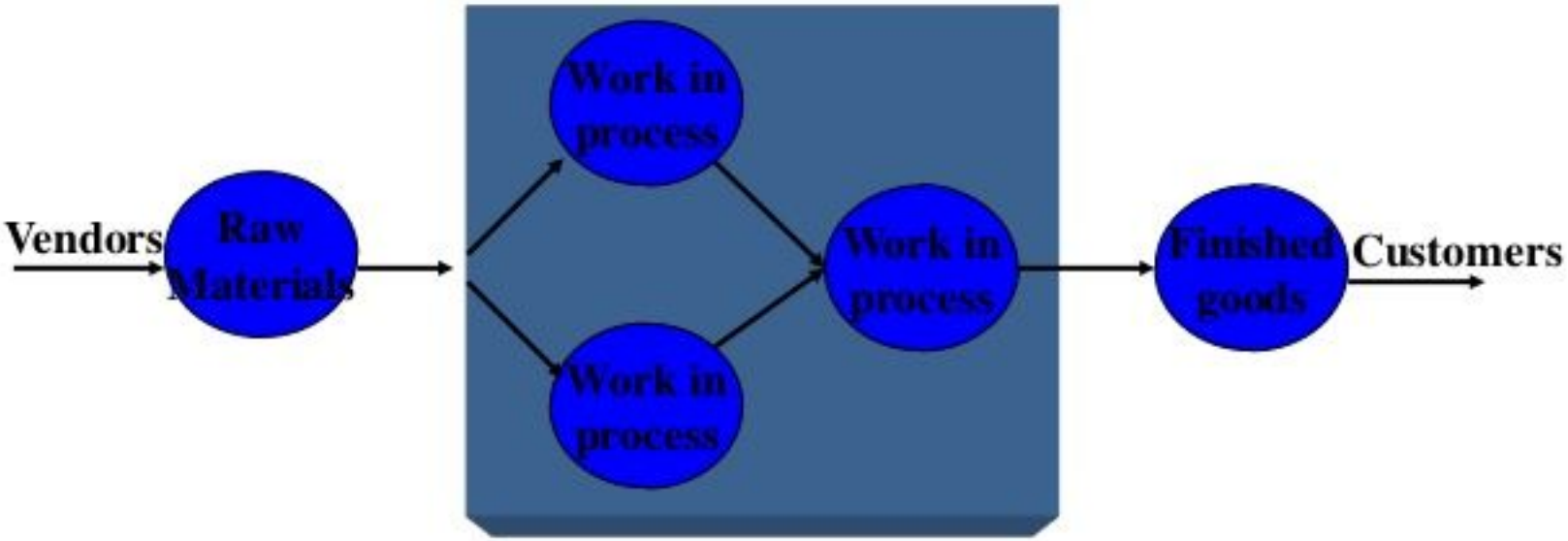
Issues under consideration

- Types of inventories
- ABC-analysis
- XYZ-analysis
- Total logistics costs
- Economic order quantity model
- Inventory control models

Inventory (stock)

- materials in a supply chain or in a segment of a supply chain, expressed in quantitie

TYPES OF INVENTORY…



DISTRIBUTION OF INVENTORY ACCOUNT

	Raw Materials	WIP Inventory	Finished goods at factory	Finished goods at distribution
Capital goods	60%	20%	20%	00%
Garment industry	30%	55%	5%	10%
Consumer product	5%	10%	30%	55%

.....TYPES OF INVENTORY

- **Raw Materials** – Basic inputs that are converted into finished product through the manufacturing process.
- **Work-in-progress** – Semi-manufactured products that need some more work before they become finished goods for sale.
- **Finished Goods** – Completely manufactured products ready for sale.
- **Supplies** – Office and plant cleaning materials that do not directly enter production but are necessary for production process and do not involve significant investments.

Stock classification by the reason of keeping

- Cycle stock
- Safety stock
- Seasonal stock
- „Speculation” stock
- Strategic stock

Reasons for inventories

- Cycle stock:
  - Lack of possibilities to fully synchronize supplies with consumption
- Technical and/or organizational conditions (limitations),
  Economic incentives (discounts).
- Safety stock:
  Random fluctuations of demand,
- Forecast errors,
  Long replenishment lead times,
- Unpredictable delays,
- Required service level.
- Surplus stock:
  Miscalculation of factors influencing safety stock,
  - Wrong estimation of the required service level,
  - Excessive safety measures taken to avoid stock-outs

Stock classification by rotation

- Fast moving (rotating) stock
- Slow moving (rotating) stock
- Not moving (rotating) stock
- Obsolete stock
- Emergency stock

Factors affecting stock size and maintaining

- uncertainty of real demand,
- uncertainty of real quantity, quality and timing of deliveries,
- seasonal access to some materials and goods,
- service level required by a customer,
- expected difficulties with an access to some goods (expected rise of prices),
- discounts offered for purchases of larger quantities,
- some technical and/or organisational conditions of deliveries

Order cycle **service level**

- probability that demand will not exceed supply during lead time (amount of stock on hand will be sufficient to meet demand).
- service level of 95% implies a probability of 95% that demand will not exceed supply during lead time.
- Risk of a stockout is the complement of service level; a customer service level of 95 percent implies a stockout risk of 5 percent.
- service level = 100% - stockout risk

EMERGING TRENDS IN INVENTORY MANAGEMENT

- Entering into long term contracts at a fixed price to reduce uncertainties.
- Just-in-time.
- Kanbans – Japanese technique (Only produce when demand comes).
- Internet based ordering systems.
- Supply chain management.
- Vendor development.
- Investment in plant and machinery.

CLASSIFICATION OF INVENTORY

- ABC Classification(consumption) (25/80+15/15+70/05)
- XYZ Classification(value stored) (Hi,Med,Low)
- HML Classification(unit-value stored) (Hi,Med,Low)
- VED Classification(spare parts mainly) (Vital,Ess,Des)
- FSN Classification(consumption) (Fast, Slow, Non)
- SOS Classification(agriculture) (Seasonal, Non)
- SDF Classification(availability) (Scarce, Difficult, Easy)
- GOLF Classification (source of supply) Govt, Ordinarily available, Local and Foreign)

Inventory Fundamentals

ABC Inventory Control: • Controlling individual items

- What is the importance of inventory item? - How are they to be controlled?
- How much should be ordered at one time? - When should an order be placed?

A B C ANALYSIS

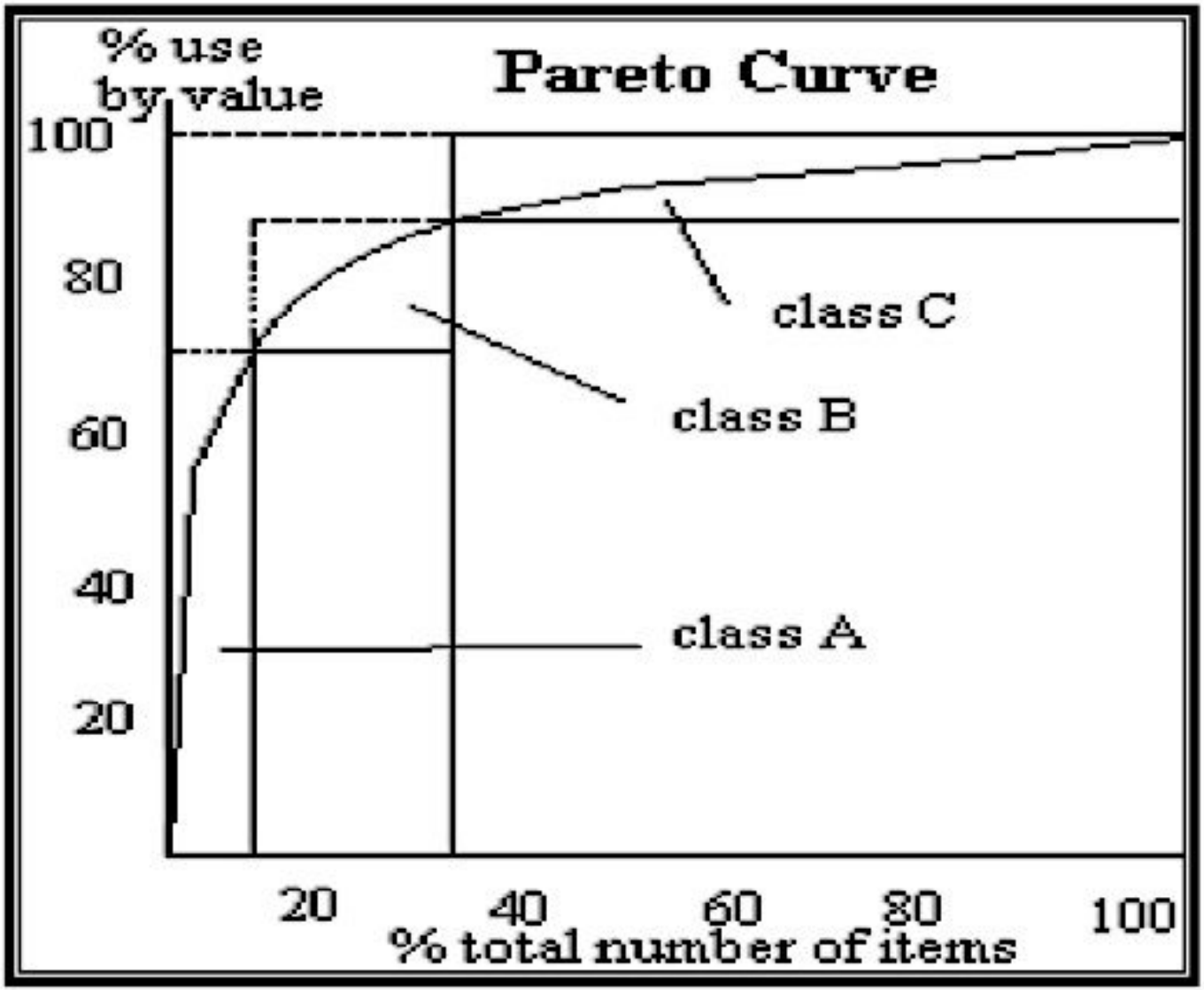
- Always Better Control
- Analytical technique for classification of inventory items was first introduced by an AMERICAN FIRM- GENERAL ELECTRIC COMPANY.
- Three categories of inventory items A, B and C type depending upon their percentages of consumption.

ABC Classification of Inventory Items

- A items : 70% of the annual consumption of inventory is covered by only 10% of the items in the inventory, deserve highest attention
- B items : 20% of the items covering 20 % of the inventory investment(less stringent control)
- C items : rest 70% of the inventory items (very little control).

ABC - analysis

Group	Share in number of items	Share in the total inventory costs
A	10-15%	70-90%
B	15-20%	15-20%
C	70-90%	10-15%


Pareto Curve
% use by value
100
80
60
40
20
class C
class B
class A
20
40
60
80
100
% total number of items

POLICIES FOR 'A' GROUP ITEMS

- Develop class A suppliers more
- Forecast A items more carefully
- Purchasing department make maximum efforts to expedite and delivery of these items
- Purchase of these items in hands of top officials
- The stock report of 'A' items should be sent more frequently, say at least once in 15 days.

POLICIES FOR 'B' GROUP ITEMS

- Order quantities, re-order stocks and safety stock should be fixed and revised for 'B' items at least one in every 4 to 6 months.
- B items should be ordered less frequently than A items

POLICIES FOR 'C' GROUP ITEMS

- Large quantities can be brought at a time, as total investment will be least.
- Paper work can be reduced considerably if orders are placed once or twice a year.
- The source of supply can be one or two based on their reliability.

ABC-анализ

- **Группа А** - тщательное планирование, постоянный (возможно, даже ежедневный) и детальный учет и контроль. Для нее рассчитывается оптимальный размер заказа.
- **Группа В** - обычный контроль, налаженный учет (возможно, ежемесячный). Размер заказа определяется с учетом скидок, например, за объем партии и условий транспортировки
- **Группа С** - упрощенные методы планирования, учета и контроля. Размер закупок рассчитывается на основе статистики расхода за прошлые периоды

Criteria	A type	B type	C Type
Quantity	10%	20%	70%
Annual Usage	70%	20%	10%
Control	Very strict	Moderate	Less
Ordering	Daily/weekly	Monthly	Yearly
Safety stock	Less	Moderate	High
Handled By	Senior officers	Middle management.	Fully delegated.

Inventory Fundamentals

Procedure for classifying by annual $ values: (5 steps)

1. Determine annual usage
2. Multiply annual usage by its cost; total annual $ usage
3. List items according to their annual $ usage
4. Calculate the cumulative annual $ usage and cumulative percentage of the items
5. Examine the annual usage distribution and group the items into A, B and C groups based on annual percentage usage

Порядок АВС-анализа

Исходные данные: годовая потребность в каждом материале в натуральном выражении; цена материала.

1. Рассчитаем для каждого материала и суммарную годовую потребность в стоимостном выражении
2. Рассчитаем долю каждого материала в общей стоимости
3. Ранжируем материалы в порядке убывания
4. Расположим материалы в порядке возрастания рангов
5. Выделим группы A, B, C

№ материала	Годовая потребность в натуральном выражении	Цена за единицу, руб.
1	1250 штук	30,00
2	10 кг	75,00
3	15.000 м	2,50
4	80.000 рулонов	12,00
5	5 тонн	7000,00
6	2.000 штук	2,12
7	850 литров	65,00
8	1.000.000 экз.	0,02
9	275 штук	1,00
10	17.200 куб. м	0,05
11	220 упаковок	2,85
12	600 штук	1.200,00

TABLE 1: DETERMINATION OF RANKS BY ANNUAL USAGE IN US$

Item #	Average usage (units)	Unit cost (US$)	Annual usage (US$)	Rank
1	17	2.5		
2	50	17		
3	15	15		
4	25	17		
5	5	17		
6	50	119		
7	153	5		
8	20	2.125		
9	16	2.656		
10	17	2.5		

Advantages

- **CONTROL** : Stocking a better mix of the right inventory allows a company to control **over-supply** and **under-supply** of important SKUs.

- **COST** : Once a company has determined which items fall into each ABC category it can establish cost-reduction initiatives at the SKU level.

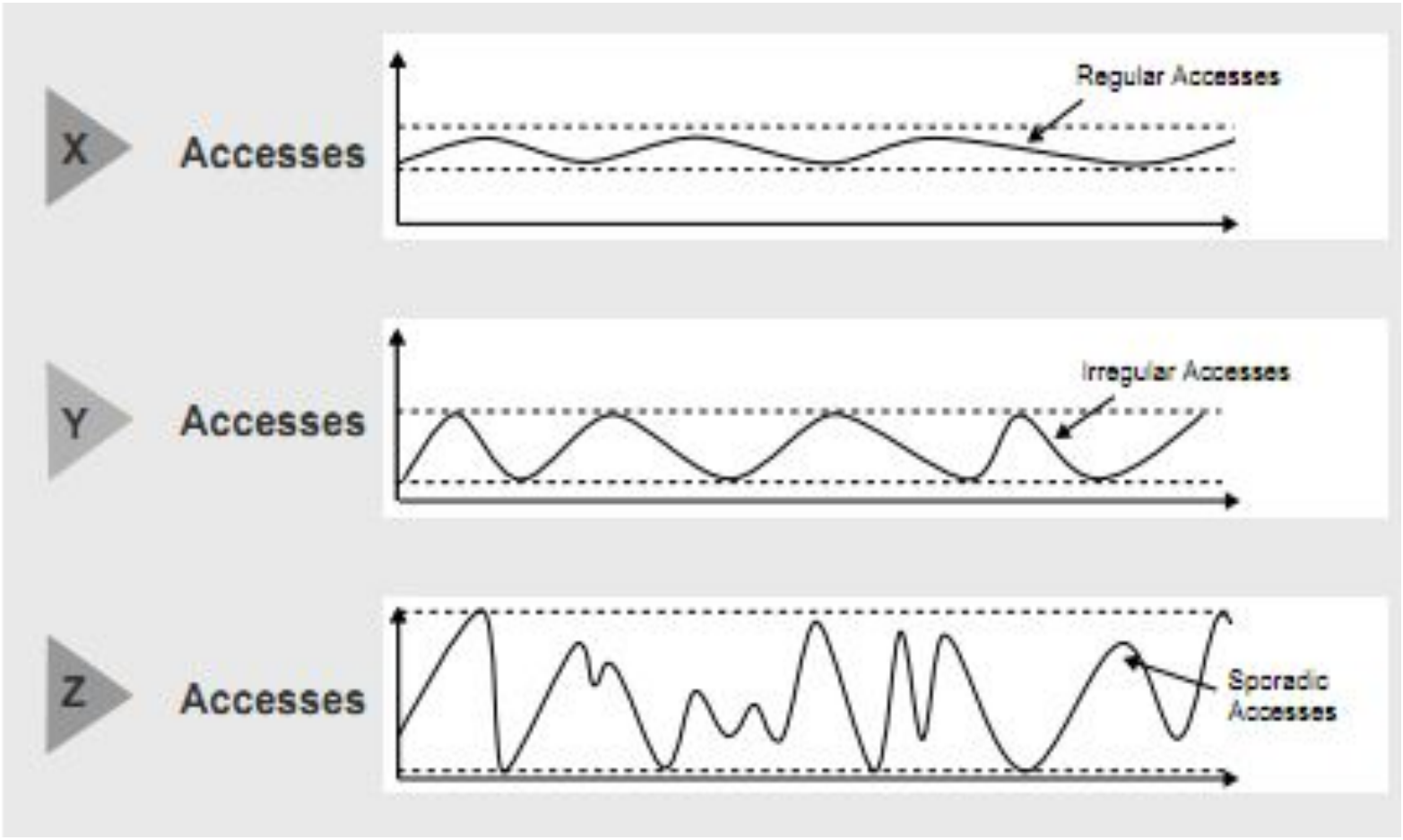
- **IMPROVED SERVICE** : Improvement in customer service levels and order fulfillment. ABC analysis provides a company with information to stock the right-mix of inventory.

- **WAREHOUSING** : ABC inventory extends to warehouse management has well. Companies utilizing ABC analysis in the warehouse give priority space to faster moving

XYZ analysis

- is a procedure of inventory management,
- on the basis empirical experiences,
- provides a classification by bill explosions or by the determination by variation and/or fluctuation coefficients of goods and articles concerning its turnover regularity (consumption and its predictableness)
- X - constant consumption, fluctuations are rather rare
- Y - stronger fluctuations in consumption, usually for trend-moderate or seasonal reasons
- Z - completely irregular consumption

Fluctuations size



XYZ –анализ

- Группа X - ресурсы характеризуются стабильной величиной потребления, незначительными колебаниями в их расходе и высокой точностью прогноза (K<10%) (или K< 50%)
- Группа Y - ресурсы характеризуются известными тенденциями определения потребности в них (например, сезонными колебаниями) и средними возможностями их прогнозирования (10%<K<25%) (или 50%<K<100%)
- Группа Z - потребление ресурсов нерегулярно, какие-либо тенденции отсутствуют, точность прогнозирования невысокая (K>25%) (или K>100%)

Разбиение на группы X,Y,Z

группа	k	k	Доля в номенклатуре
X	Менее 10%	Менее 50%	5-10%
Y	10-25%	0-100%	Около 25%
Z	Более 25%	Более 100%	Около 70%

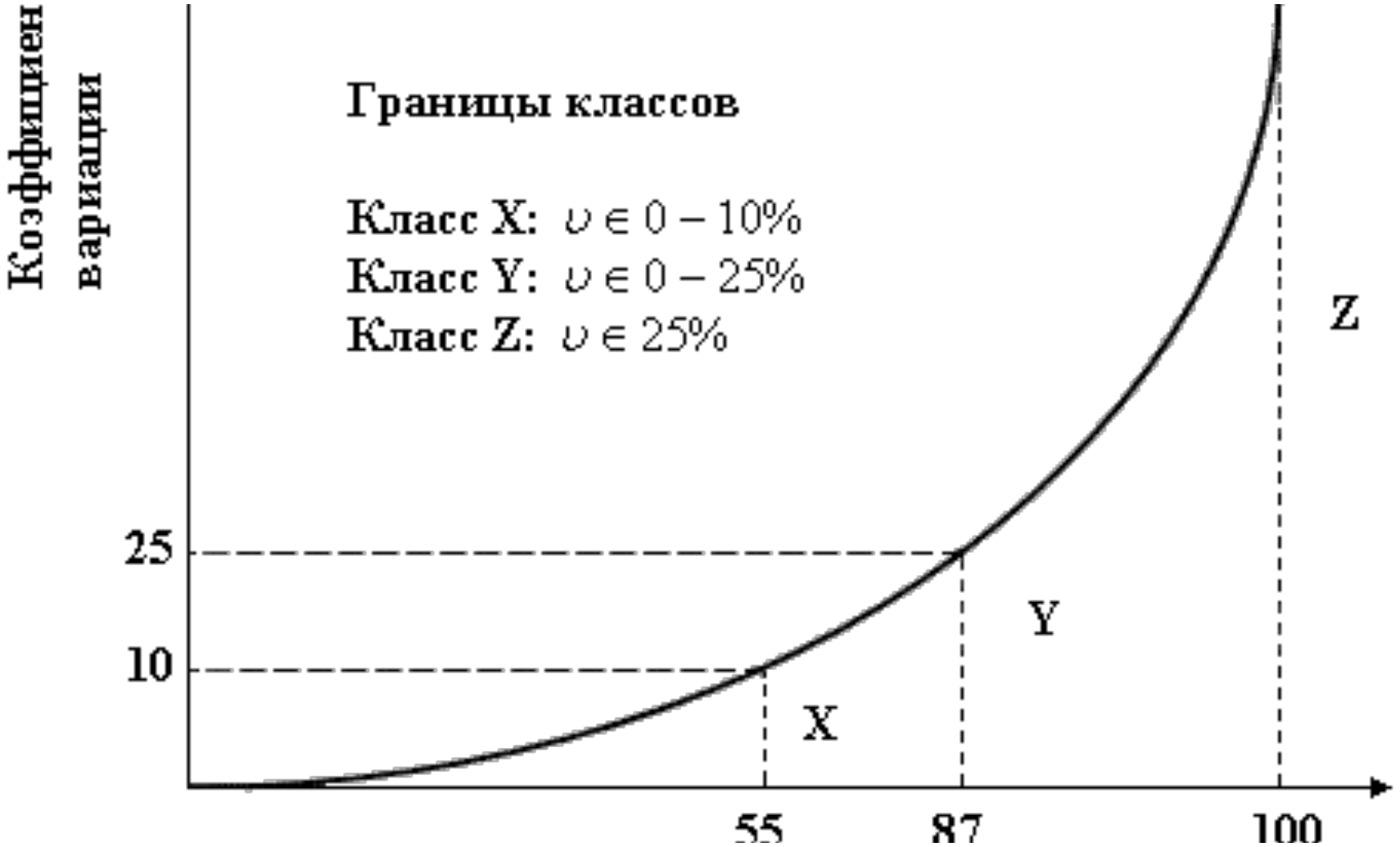
Thus

- X materials are characterized by a constant, non-changing usage over time. The requirements fluctuate only slightly around a constant level so that the future demand can basically be forecast quite well.

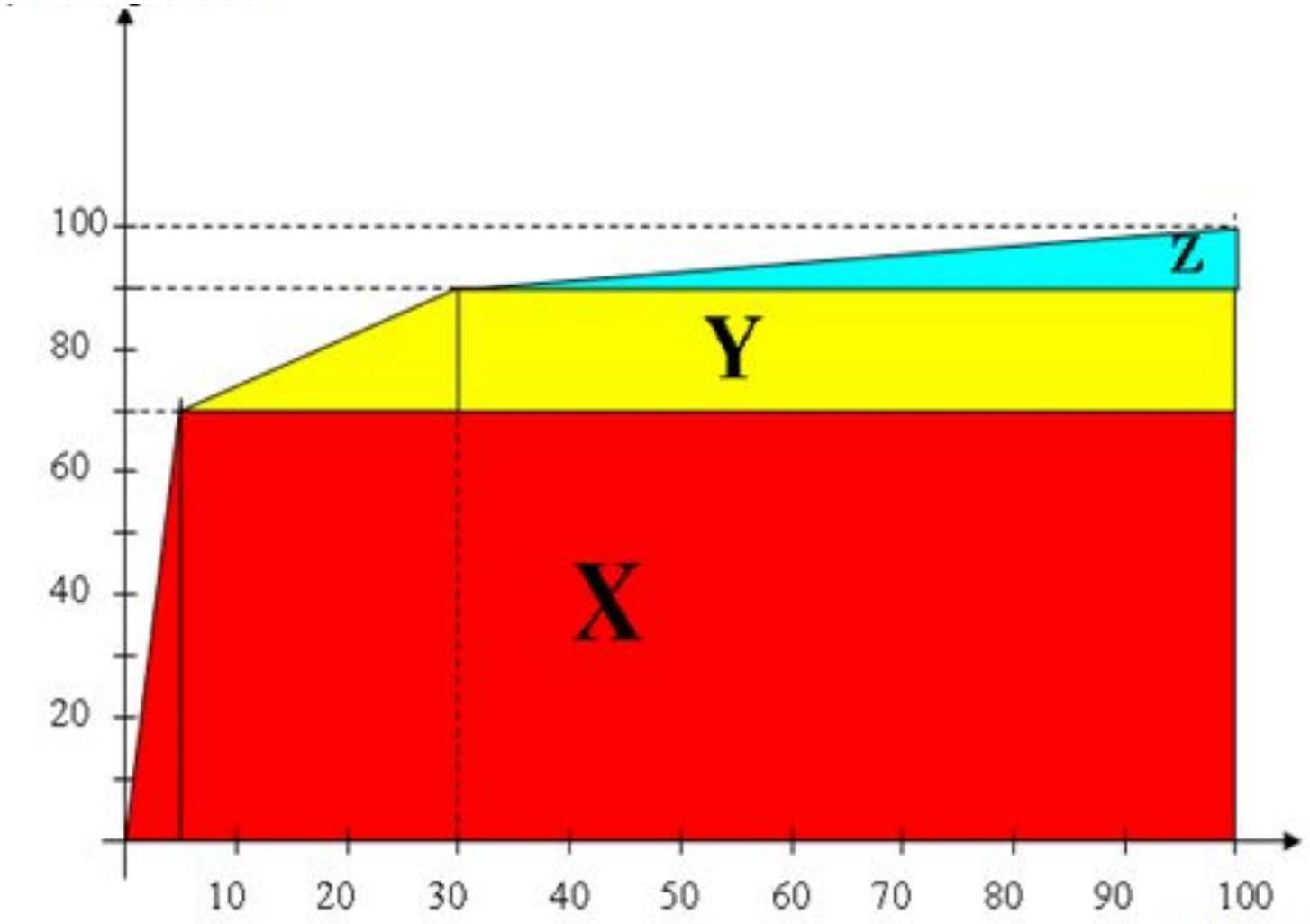
- Y materials The usage of these materials is neither constant nor sporadic. With Y materials, we can often observe trends, for example, that the usage increases or decreases for a while, or that it is characterized by seasonal fluctuations. For these materials, it's harder to obtain an accurate forecast.

- • Z materials These materials are not used regularly. The usage can strongly fluctuate or occur sporadically. In these cases, we can often observe periods with no consumption at all.

XYZ-анализ


Коэффициент вариации
Границы классов
Класс X: υ ∈ 0 – 10%
Класс Y: υ ∈ 0 – 25%
Класс Z: υ ∈ 25%
25
10
X
Y
Z
55
87
100

The chart



Порядок XYZ-анализа

1. установить средний расход каждого вида материала с учетом колебания потребности в них по периодам
2. рассчитать коэффициент вариации по каждой номенклатурной позиции;
3. расположить материалы по мере убывания коэффициентов вариации;
4. суммировать данные о количестве материалов в соответствии с возрастанием коэффициентов вариации, нанести их на схему;
5. разбить материалы на группы

Material number	Material-denotation	Average price	Consumption	Operands for determining the variation coefficient				Ranking
		[€/ unit]	[unit]	$\bar{V} = \frac{\sum V_n}{N}$	$s = \sqrt{\frac{1}{N}\sum (V_n - \bar{V})^2}$	$\frac{s}{\bar{V}}$	VC [%]	
			V_n					
100101	M1	15	226.200	18.850	7.142	0,38	38%	2
100102	M2	300	81.900	6.825	3.616	0,53	53%	5
100103	M3	10	181.110	15.093	6.860	0,45	45%	3
100104	M4	650	34.900	2.908	1.504	0,52	52%	4
100105	M5	35	11.300	942	993	1,05	105%	10
100106	M6	25	94.800	7.900	2.115	0,27	27%	1
100107	M7	45	23.100	1.925	1.238	0,64	64%	6
100108	M8	20	118.200	9.850	6.579	0,67	67%	7
100109	M9	450	16.200	1.350	1.237	0,92	92%	8
100110	M10	750	38.300	3.192	3.283	1,03	103%	9

Inventory control policy

- X class items which are critically important and require close monitoring and tight control – while this may account for large value these will typically comprise a small percentage of the overall inventory count.
- Y class are of lower criticality requiring standard controls and periodic reviews of usage.
- Z class require the least controls, are sometimes issues as “free stock” or forward holding.

Cons. regularity / Cons. value	X	Y	Z
A	AX	AY	AZ
B	BX	BY	BZ
C	CX	CY	CZ

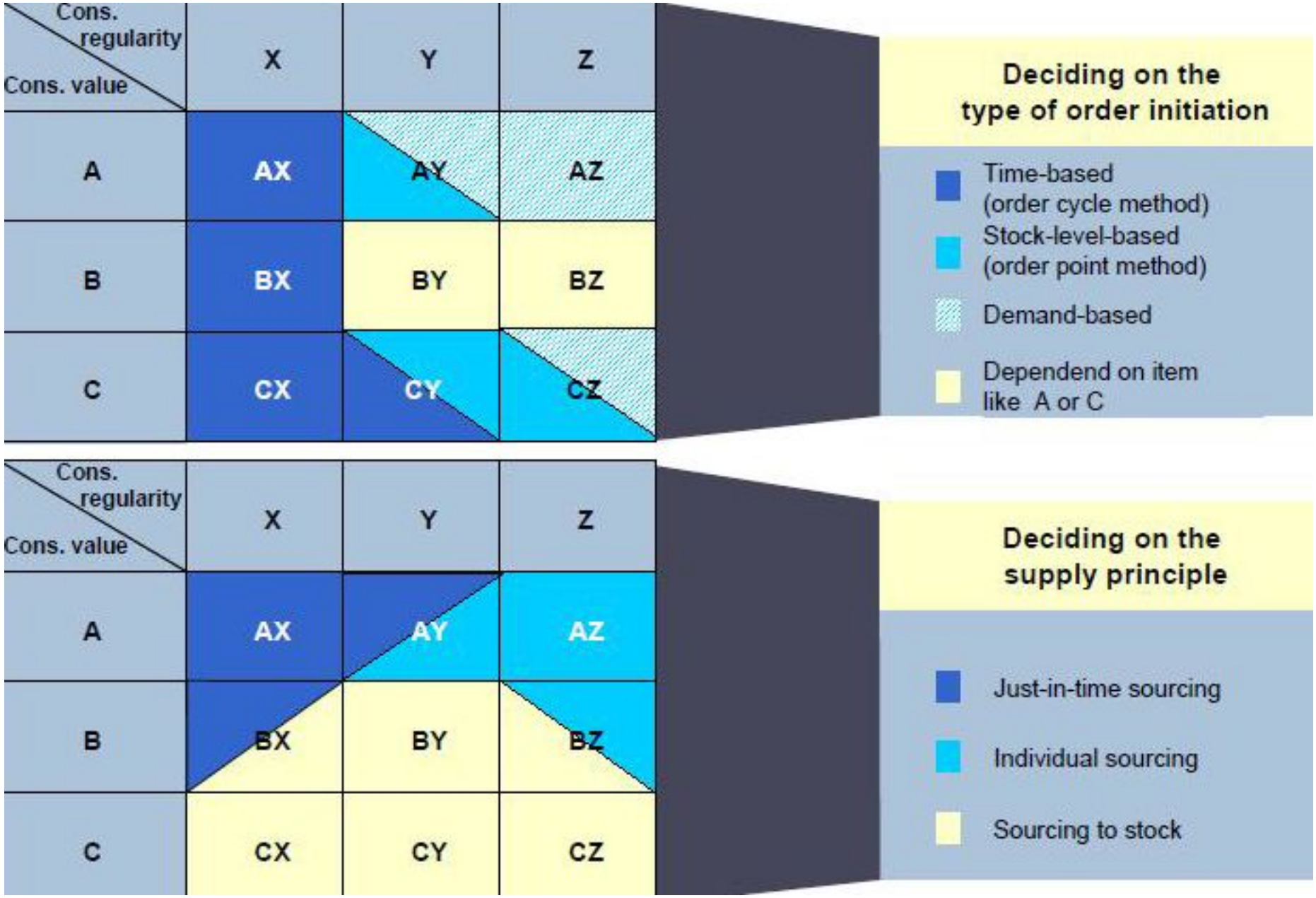
Deciding on the degree of automation

- Fully automated
- Partly automated
- Manual

Cons. regularity / Cons. value	X	Y	Z
A	AX	AY	AZ
B	BX	BY	BZ
C	CX	CY	CZ

Deciding on the method of analysing requirements

- Deterministic requirements planning
- Stochastic requirements planning
- Dependend on item like A or C


Cons. regularity
Cons. value
X
Y
Z
A
AX
AY
AZ
B
BX
BY
BZ
C
CX
CY
CZ
Deciding on the type of order initiation
Time-based (order cycle method)
Stock-level-based (order point method)
Demand-based
Dependend on item like A or C
Cons. regularity
Cons. value
X
Y
Z
A
AX
AY
AZ
B
BX
BY
BZ
C
CX
CY
CZ
Deciding on the supply principle
Just-in-time sourcing
Individual sourcing
Sourcing to stock

Types of Inventory Costs

- Ordering (purchasing) costs
- Inventory carrying (holding) costs
- Out of stock/shortage costs
- Other costs

Inventory Fundamentals

Inventory costs:

1. Item cost
   - landed price
     - purchase cost
     - cost to get it in plant
       - transportation
       - custom duties
       - insurance
2. Carrying cost
3. Ordering cost
4. Stock out cost
5. Capacity associated costs

Inventory Fundamentals

Inventory costs:

1. Item cost
2. Carrying cost
   - Cost of carrying volume of inventory
   - Capital cost
   - Storage cost
     - Space
     - Labor
     - equipment
   - Risk cost
     - Obsolescence: model change, out dated
     - Damage: in handling
     - Pilferage: lost, misplace, stray, stolen
3. Ordering cost
4. Stock out cost
5. Capacity associated costs

Inventory Fundamentals

Inventory costs:

1. Item cost
2. Carrying cost
3. Ordering cost
   - Associated with placing an order with a factory or supplier
   - Independent of quantity order
   - Depends on number of orders placed in a year
   - Production control cost
     - Setup time
     - Tear down at the end of run
     - *Production loss
   - Lost capacity cost
     - Incurred when an order is placed
       - Order preparation
       - Follow-up
       - Authorizing payment
       - * Expediting
       - * Receiving
       - * Receiving and paying invoice

Inventory Fundamentals

Inventory costs:

1. Item cost
2. Carrying cost
3. Ordering cost
4. Stock out cost
   - If demand during the lead time exceeds forecast we expect a stock out
     - Back order cost
     - Lost sale
     - Lost customer
5. Capacity associated costs

Inventory Fundamentals

Inventory costs:

1. Item cost
2. Carrying cost
3. Ordering cost
4. Stock out cost
5. Capacity associated costs
   - When output level is changed, following cost may incur
     - i. Overtime
     - ii. Hiring
     - iii. Leveling production
     - iv. Carrying inventory
     - v. Training
     - vi. Extra shift
     - vii. Laying off

Economic Order Quantity

- Оптимальный размер заказа – такой, который минимизирует совокупные издержки обеспечения на складе (P) необходимого количества материала (Q), в определенное время (T)

Совокупные издержки

1. Издержки закупки
- Условно-переменные, зависят от количества закупаемого материала
- Условно-постоянные, связаны с размещением заказа, не зависят от размера заказа
2. Издержки транспортировки (условно-постоянные ->условно-переменные)
3. Издержки хранения
- Явные
- Неявные

1а.Условно-переменные

- = количество материала х цену единицы

Пропорциональная зависимость, но:

- ✔ Скидки за объем

16. Расходы на размещение заказа

- поиск поставщика
- ведение переговоров
- оформление и отправка заказа
- отслеживание транспортировки
- анализ информации по движению запаса
- принятие заказа по его прибытии
- оформление претензий по качеству
- сверка документов
- ведение счетов поставщика
- другие

Расчет издержек на размещение заказа

= общие расходы отдела закупок за год/ число заказов за год

общие расходы отдела закупок за год:

- заработная плата работников отдела
- материальные и накладные расходы
- командировки
- расходы на проведение переговоров и презентаций

2. Издержки транспортировки:

По экономической сути - условно-постоянные в определенном диапазоне

- На практике для удобства расчетов – условно-переменные (рассчитаны на тонну, км, тонно-км, час)
- Порядок расчета:
- Совокупные издержки по обслуживанию транспортного парка за период / количество тонн (тонно-км, часов)

3а. Явные издержки

- заработная плата работников склада;
- аренда складских помещений и оборудования;
- текущие расходы на содержание склада;
- зарплата управленческого персонала;
- стоимость израсходованных при приемке материалов;
- затраты на упаковку, сортировку;
- потери от естественной убыли;
- убытки от снижения потребительских качеств товара в результате хранения;
- стоимость страхования
- налоги.

3б. Неявные издержки

- Издержки замораживания капитала в запасах:
- Недополученная прибыль
- Стоимость привлечения капитала

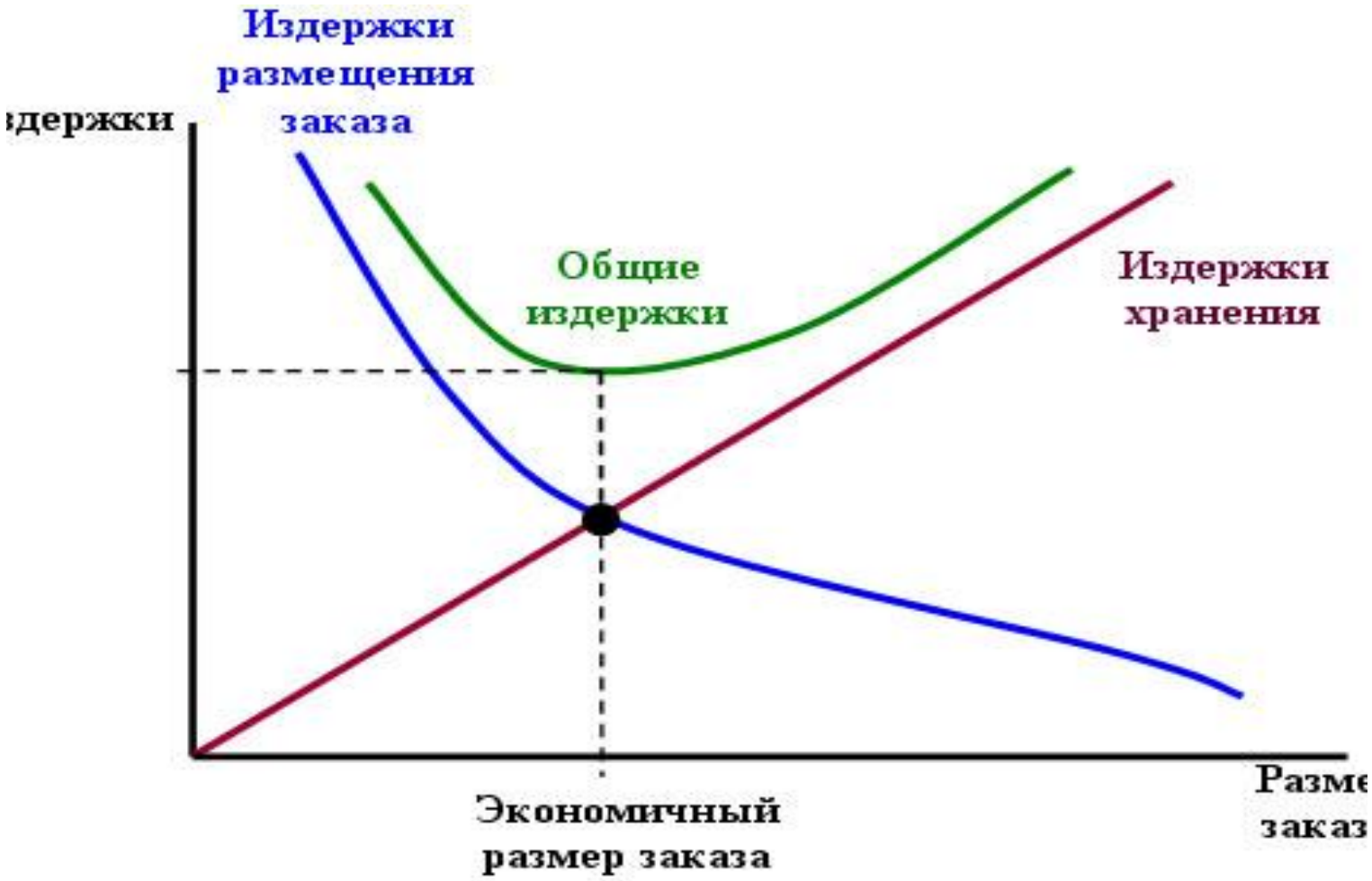
- Как правило, стоимость получения кредита в банке (ставка процента по кредитам)

Модель оптимального размера заказа (предпосылки)

- интервал времени между поставками постоянен и время доставки постоянно
- каждый заказ поставляется в виде одной партии
- отсутствуют ограничения по производственным мощностям склада
- страховой запас отсутствует
- отсутствуют потери от дефицита
- поставщик может поставлять любой размер партии

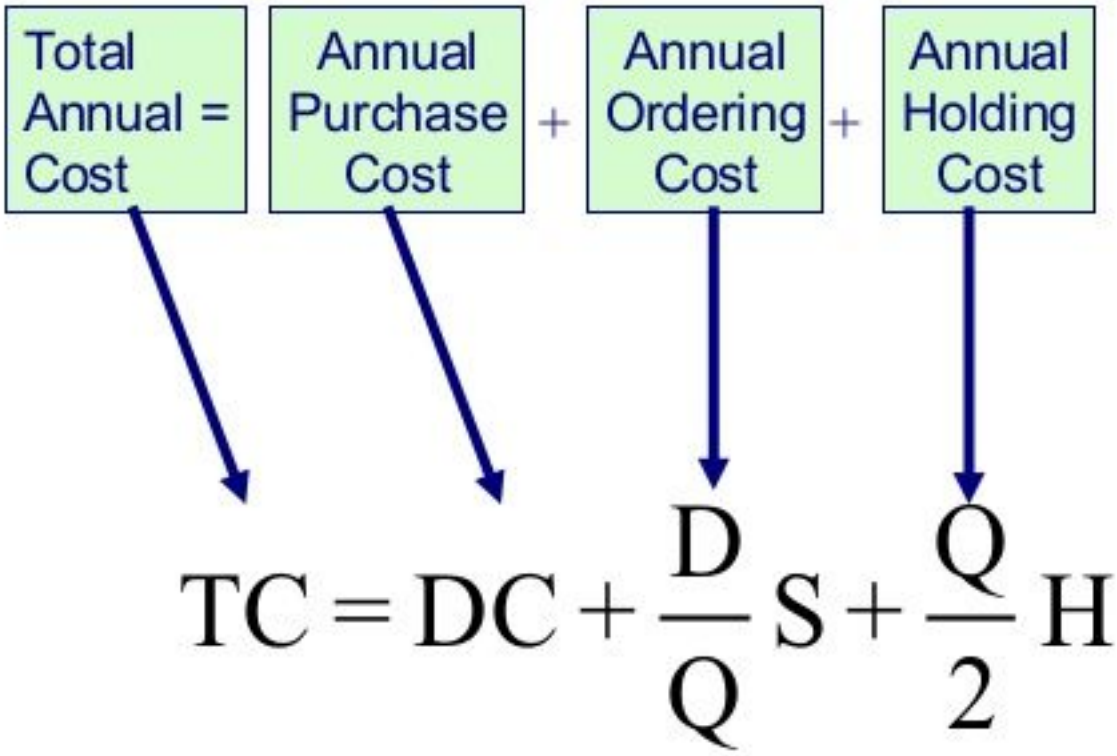
Assumptions for EOQ model

- Only one product is involved.
- Annual demand requirements are known.
- Demand is spread evenly throughout the year so that the demand rate is reasonable constant.
- Lead time does not vary
- Each order is received in a single delivery.
- There are no quantity discounts.



Оптимальный размер заказа

Basic Fixed-Order Quantity (EOQ) Model Formula



TC=Total annual cost
D =Demand
C =Cost per unit
Q =Order quantity
S =Cost of placing an order or setup cost
R =Reorder point
L =Lead time
H=Annual holding and storage cost per unit of inventory

Модель оптимального размера заказа (предпосылки)

1. M (ед.) – годовая потребность в материале, расходуется со склада равномерно
2. P (руб.) – цена материала, включает в себя транспортные издержки, не изменяется
3. K (руб.) – стоимость обслуживания одного заказа
4. Z (в долях) – средние годовые издержки хранения единицы материала на складе
5. Q (ед.) – оптимальный размер заказа

Пример

- Годовая потребность в материала 1000 единиц
- Цена единицы материала – 2 руб.
- Стоимость размещения заказа – 10 руб.
- Страховой запас на 10 дней работы
- Стоимость хранения в год составляет 0,3 от средней стоимости материала на складе
- Рассчитать: оптимальный размер заказа, средний и максимальный размер запаса на складе, график поставок

Потери при отсутствии запаса (издержки дефицита)

Отсутствие запаса – невозможность осуществления заказа, реакция клиента:

1. Отложенный заказ: издержки повторной подготовки заказа
2. Потеря заказа: (1) + прибыль от заказа
3. Потеря клиента :

- потеря всех будущих прибылей
- издержки поиска новых клиентов

Fixed-order-interval (FOI) model

- is used when orders must be placed at fixed time intervals (weekly, twice a month, etc.)
- widely used in retail businesses (e.g., drugstores, small grocery stores).
- Reasons of using:
- a supplier's policy might encourage orders at fixed intervals;
- grouping orders for items from the same supplier can produce savings in shipping costs;
- some situations do not require continuous monitoring of inventory levels, only periodic check is needed.

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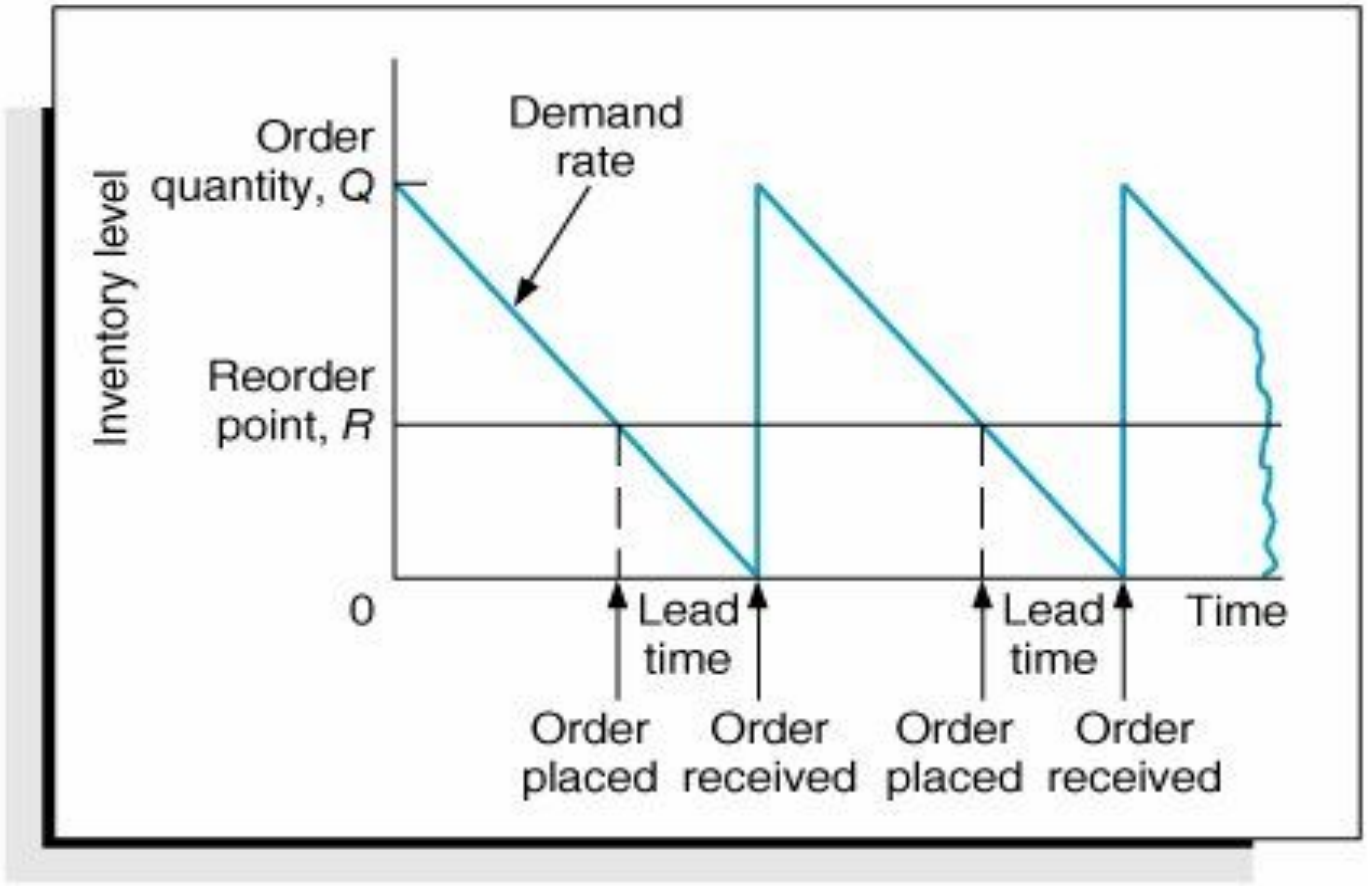
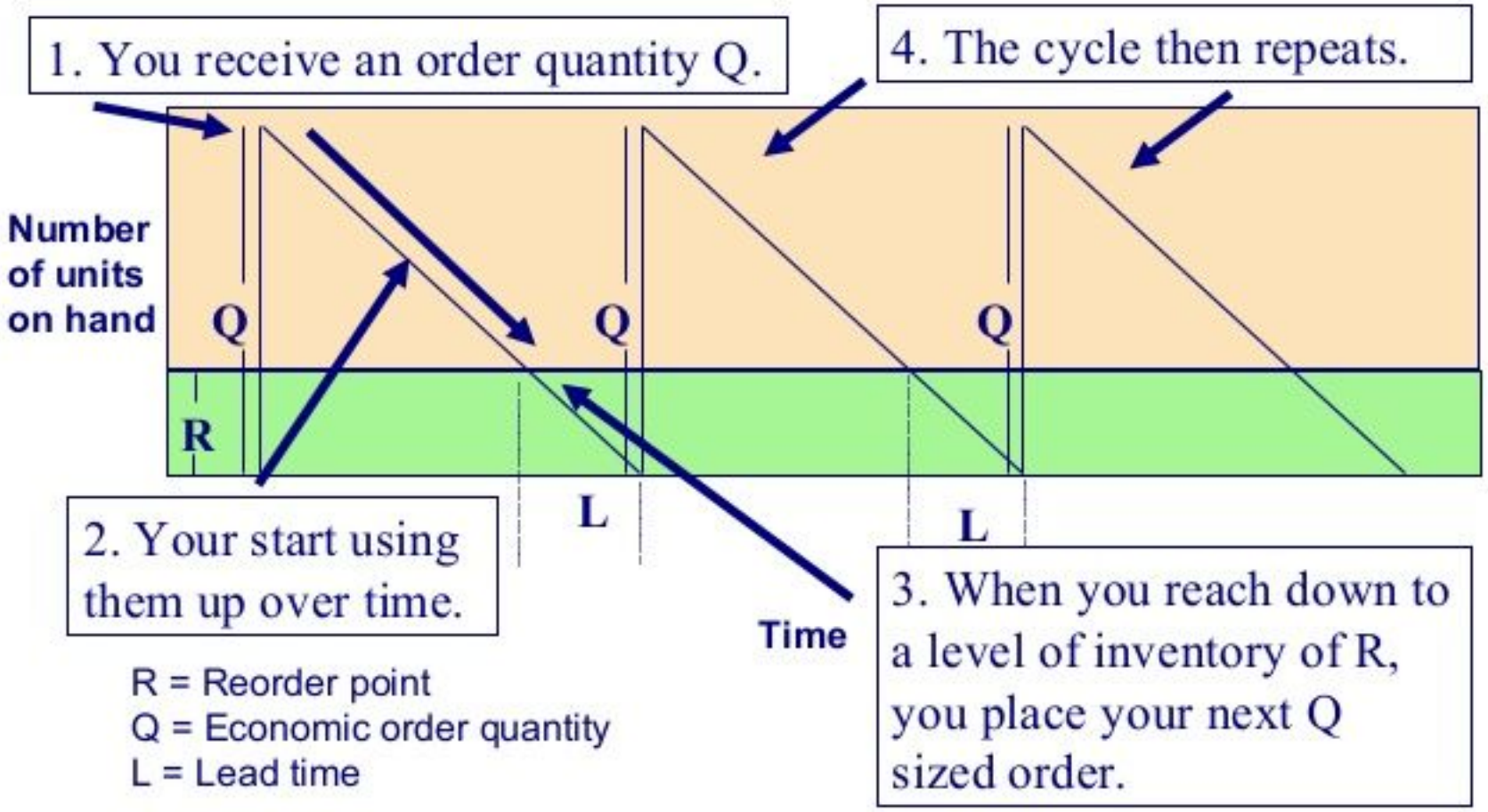
Order Quantity= Average demand over the vulnerable period+ Safety Stock- Inventory currently on hand



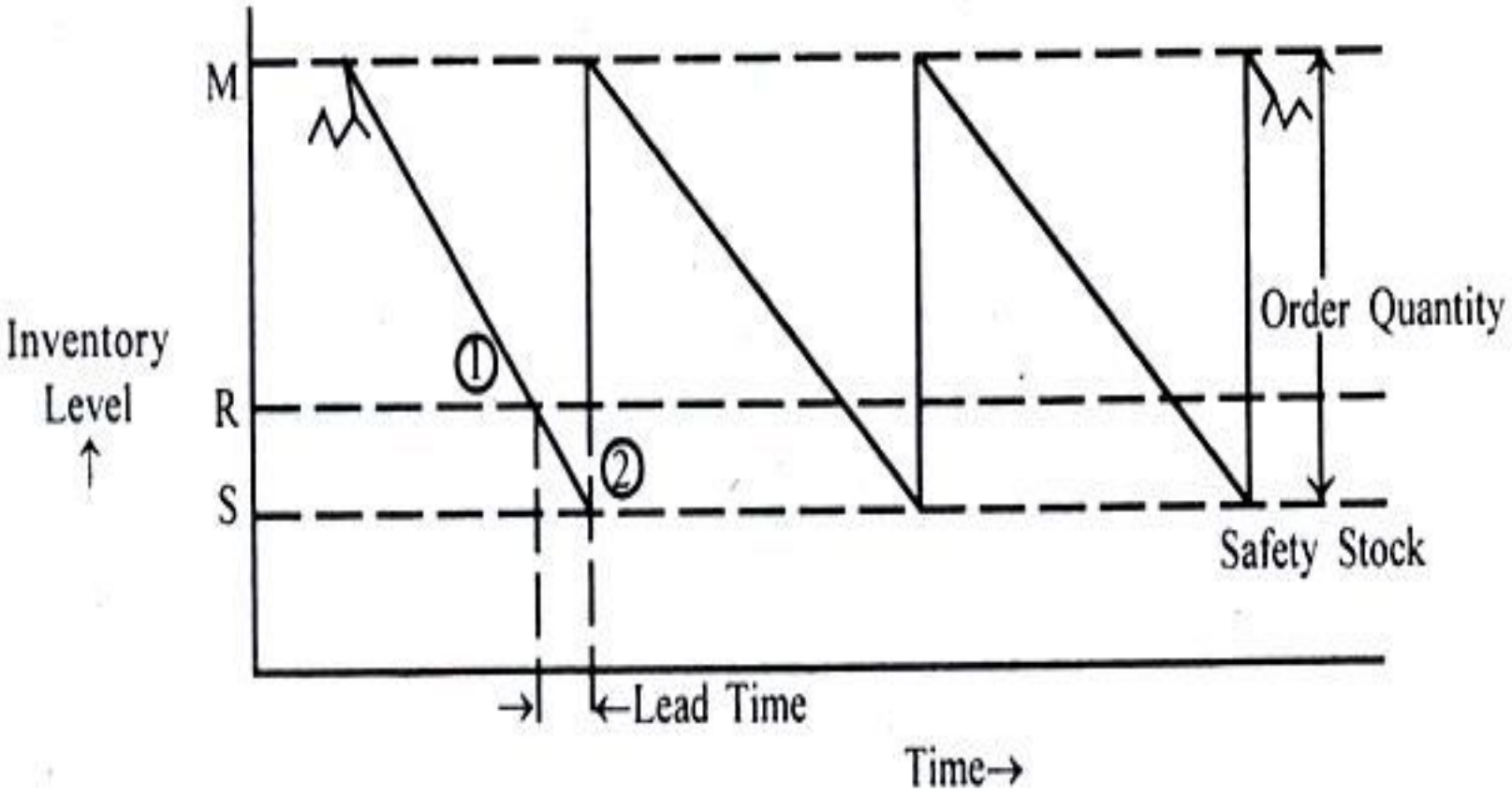
Fixed-interval system

- results in the tight control needed for A items in an A-B-C classification due to its periodic reviews.
- when two or more items come from the same supplier, grouping orders can yield savings in ordering, packing, and shipping costs.
- may be the only practical approach if inventory withdraws cannot be closely monitored.
- On the negative side, the fixed-interval system needs a larger amount of safety stock for a given risk of stockout, to protect against shortages during an entire order interval plus lead time (instead of lead time only), and this increases the carrying cost. Also, there are the costs of periodic reviews.

Basic Fixed-Order Quantity Model and Reorder Point Behavior



Fixed quantity model diagram



Comparison of models

- Both models are sensitive to demand experience just priori to ordering, but in somewhat different ways.
- In the fixed-quantity model, a higher-than-normal demand causes a *shorter time* between orders, whereas in the fixed-interval model, the result is a *larger order size*.
- Fixed-quantity model requires close monitoring of inventory levels in order to know *when* the amount on hand has reached the reorder point.
- The fixed-interval model requires only a periodic review (i.e., physical inspection) of inventory levels just priori to placing an order to determine how much is needed.
- If both the demand rate and lead time are constant, the fixed-interval model and the fixed-quantity model function identically.