Productie en logistiek beleid

Productie- en logistiek beleid (Universiteit Gent)

PRODUCTIE EN LOGISTIEK BELEID

Introduction to operations management

What is operations management?

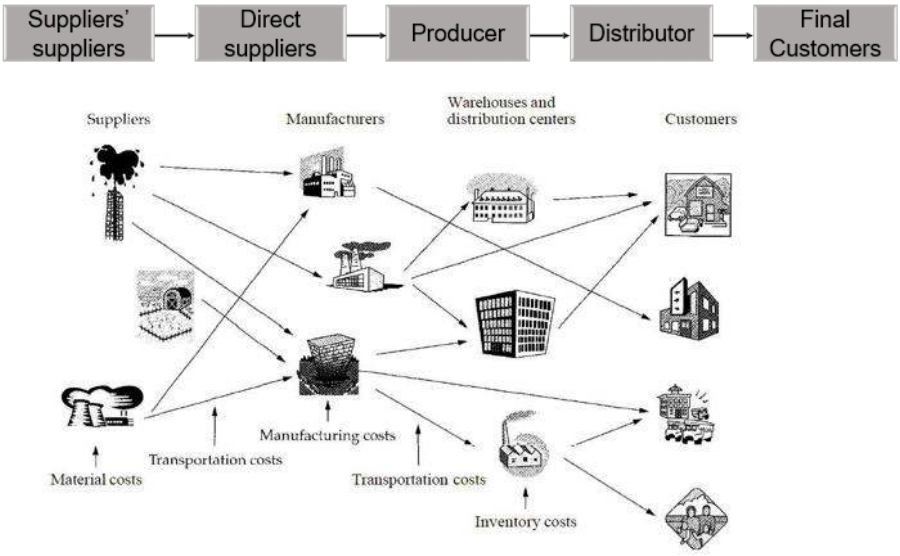
- "Operations management is the planning, scheduling and control of the activities that transform inputs into finished goods and services."
- "Operations management deals with the design and management products, processes, services and supply chains. It considers the acquisition, development and utilization of resources that firms need to deliver the goods and services their clients want."
- "Operations management is an area of management concerned with overseeing, designing, and controlling the process of production and redesigning business operations in the production of goods or services. It involves the responsibility of ensuring that business operations are **efficient** in terms of using as few resources as needed, and **effective** in terms of meeting customer requirements. It is concerned with managing the transformation process that converts inputs (in the forms of raw materials, labor, and energy) into outputs (in the form of goods and/or services)."

→ You can be very efficient in doing something, but if it's not effective then it's still a waste of time.

Supply chain

Supply chain	A sequence of activities and organizations involved in producing and delivering a good or service.

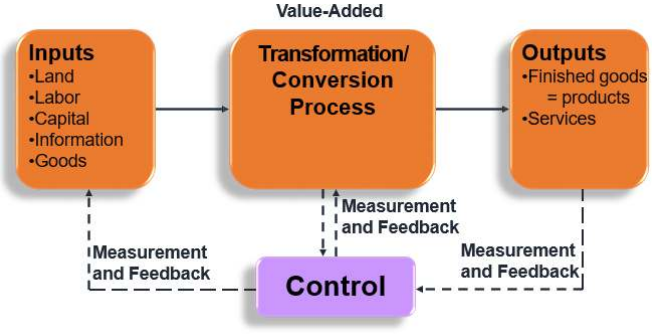
The supply chain is everything from raw material until finished product, everything that's in between. A supply **chain** might give a too simplistic view of reality, because in reality it's often more of a supply **network** then a supply **chain**!



OM = managing transformation processes

OM	= operations management. Management that is used to transfer inputs (raw materials and materials) into outputs (finished goods or services).

Outputs can be good but also services, inputs can range from information, capital, materials etc.
You have **two types of inputs**: -) inputs that need to be transformed
-) inputs that are used to transform other inputs (employees)



Feedback = measurements taken at various points in the information process.

Control = the comparison of feedback against previously established standards to determine if corrective action is needed.

Not only raw materials can be transformed, there are **3 types of typical transformation processes**:

- **Typical material processors**
  Transformation of raw materials and other materials. Food production, mining and extraction, transport, postal service, distribution, warehousing, retail operations etc.

- **Typical information processors**
  Transformation of data into useful information. Accountants, bank offices, market research organizations, telecom company, news service etc.

- **Typical people processors**
  Transformation of people. For example when they go to the hairdresser, hotels, hospitals, theme parks, dentists, schools, theatres etc.

Productions of goods vs delivery of services

Goods : physical items that include raw materials, parts, subassemblies and final products
Services : activities that provide some combination of time, location, form or psychological value

→ Goods and services often occur **together** for example: *having the oil changed in your car is a service, but the oil itself is a good…*

Zie slide 18 voor de kenmerken van goederen en diensten en slide 19 voor het continuum.

Manufacturing matters!

Lately we see a **shift** from the manufacturing sector to the service sector, we are developing towards a **knowledge economy**. Thought it's important to remember that many services exist to support manufacturing, they wouldn't be there if it wasn't for manufacturing!

Manufacturing naturally leads to innovation, how to make processes faster, more efficient, more effective… This creates even more manufacturing because now machines need to be made etc.

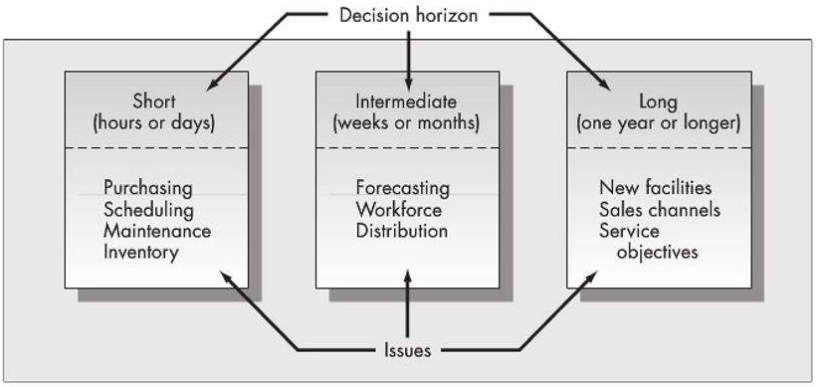
Decision horizon

In operations management you have **3 types of decisions** because even though it's called "operations" management you have more than only operational issues.

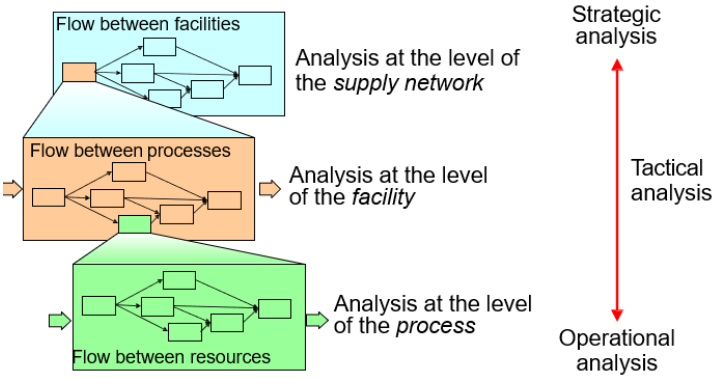
- **Strategic issues**
  Determining the size and location of manufacturing plants, deciding the structure of service and telecommunication networks and designing technology supply chains.

- **Tactical issues**
  Desicions that you've made but that you won't change on a daily basis. After several months or even years you can come back on those decisions and maybe change them. Only management levels make these decisions, not employees.

- **Operational issues**
  Who is going to work when and where, work schedules, which orders will be produced first and when will that be… These decisions you will make and change on a daily basis. Not only management but also employees can make these decisions.



You have OM decisions to analyse your entire supply chain, but you can also choose to look at specific processes instead of the entire supply chain. There are actually **three levels of analysis**:



- **Strategic**: if you're looking at the entire supply chain / supply network. The flow between facilities.
- **Tactical** : if you're analysing a facility. The flow between processes.
- **Operational**: if you're looking at only one process. The flow between resources.

→ It's also possible that you have operational issues about higher levels or strategic issues that only relate to one certain process.

So how to manage these **flows between processes**? First of all it's important to realize that there are 3 different types of flows:

- **Flow of goods**: suppliers → manufacturers → warehouses and distribution centres → customers
- **Flow of funds:** customers have to pay the suppliers for the goods they receive etc.
- **Flow of information**: to optimize the entire supply chain it's necessary to share information and give feedback

Strategy and competition

- **Business strategy**: sets the terms and goals for a company to follow, it's a long term plan of action.

The overall business strategy needs to be divided in 3 different strategies: marketing, operations and financial strategy.

- **Operations strategy**: the means by which the firm deploys its resources to achieve its competitive goals

Operations management (OM) is concerned with implementing the operations strategy to achieve leadership along one or some of these dimensions.

Some strategic dimensions are:
- cost
- quality
- flexibility
- product differentiation
- delivery speed
- delivery reliability

Operations management tools

- OM tools can be applied to **ensure that resources are used as efficiently as possible**
- OM tools can be used to **make desirable trade-offs** between competing objectives
- OM tools can be used to **redesigned or restructure our operations so that we can improve performance** along multiple dimensions simultaneously

Strategy formulation

If you want an **effective** strategy formulation then you have to take the following things into account:

- Core competences of your company
- Environmental scanning:
  - **SWOT** → internal factors: strengths and weaknesses
    → external factors: opportunities and threats

Having an effective strategy is one thing, but a **successful** strategy formulation also requires taking into account:

- **Order qualifiers**: characteristics that customers perceive as minimum standards if acceptability for a product or service to be considered as a potential for purchase
- **Order winners**: characteristics of an organization's goods or services that cause it to be perceived as better than the competition

Not all companies are bound to succeed, **some companies fail** and there are several reasons for that:

- Neglecting operations strategy, neglecting investments in capital and human resources
- Failing to take advantage of strengths and opportunities and/or failing to recognize competitive threats
- Too much emphasis on short-term financial performance at the expense of R&D
- Too much emphasis in product and service design and not enough on process design and improvement
- Failing to consider customer wants and needs, failing to establish good internal communications and cooperation

Performance measurement

Balanced scorecard approach and Key Performance Indicators (KPIs)

BSC (balanced score card)	A top-down management system that organizations can use to clarify their vision and strategy and transform them into action.

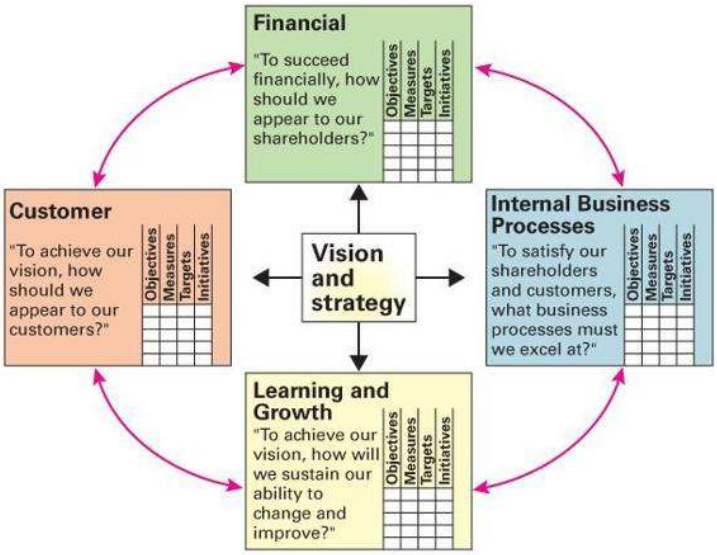
1) develop objectives

2) develop metrics and targets for each objective

3) develop initiatives to achieve objectives

4) identify links among the various perspectives
   > *finance, customer, internal business processes, learning and growth*

5) monitor results



You have to follow up what you are giving to your clients and the way in which you are delivering it to them etc. You have to follow up what you are doing, in what way you are doing it and if that is how you want to be doing it.
→ It's important that you keep moving, even if you are doing something good already you'll still want to keep track of what's changing in the market, new ways to improve, now technologies etc.

Every company should also have a **performance scorecard**, sometimes called '*supply chain dashboard*'

Performance scorecard / supply chain dashboard	A holistic set of performance metrics (and corresponding performance standards) that address the major concerns of customers, stockholders, employees and suppliers.

Implementing such a set of Key Performance Indicators (KPI's) is a prerequisite to performance improvement. Because people behave **based on the way they are measured** so **what gets measured gets improved**. Besides, it's hard to win a game without a scoreboard; it's hard to even know which game you are playing without a scoreboard. It's important to keep track of where you are now and what you're doing now, so you don't lose sight of it.

→ If you don't follow up, you won't have continuous improvement!

Productivity

Productivity = $\frac{\text{output}}{\text{input}}$

Input = labor, material, capital, energy, …
Output = product or service

Productivity = efficiency + effectiveness

Efficiency = how well are the inputs used?
Effectiveness = how well is the output made?

If you follow up productivity you follow up both efficiency and effectiveness.
→ How well do I use my inputs to generate my outputs? + How well is my output?

Productivity matters because a high productivity is linked to higher standards of living. Furthermore higher productivity, relative to the competition, leads to competitive advantage in the marketplace. So for an industry, high relative productivity makes it less likely it will be supplanted by foreign industry.

But don't make a mistake, **increase production ≠ increased productivity!**
Higher productivity means that more is produced with the **same expenditure (amount)** of resources, it's not simply the fact that there is more produced!

Although the concept of productivity is simple, measuring it is not an easy task!

AGGREGATION PROBLEM:
- → If an industry produces different types of output, a common unit of measurement is needed to obtain aggregate output.
- → The same for aggregate input when different input resources are used.

SOLUTION: express input and output in **monetary terms** or use **partial productivities** if one of the inputs or outputs is much more expensive or worth more than the others.

Forecasting

What is forecasting?

Forecast	A statement about the future value of a variable of interest. Primary function is to predict the future.

Forecasts are interesting because they affect the decision that we make today. We make forecasts about such things as weather, demand, resource availability etc.

Forecasts help managers by reducing some of the uncertainties. The better the estimate, the more informed decisions can be. Some examples:
- Forecasts about demand for products and services
- Forecasts about availability of manpower
- Forecasts about inventory and material needs
- …

Example: Ryanair did some bad forecasting, they forcasted the present of their pilots wrongly. They thought that their pilots wouldn't want to take vacation but they did …
→ This resulted in a loss of customer satisfaction because a lot of flights were cancelled.

Characteristics of forecasts

A wide variety of forecasting techniques are in use. They are quite different from each other, nonetheless some features are common to all and it is important to recognize them:

1. Assumption that the same underlying causal system from the past will persist into the future
2. Forecasts are not perfect, actual results differ from predicted values.
   Random variation is always present. There will always be some residual error, even if all other factors have been accounted for.
3. Forecasts for groups of items tend to be more accurate than for individual items.
   If you produce several types of products it's wiser to make a forecast from all the products together then to forecast the demand for product A, B and C separately.
4. A good forecast is more than a single number

5. Accuracy decreases as we go further into the future
6. Forecasts should not be used to the exclusion of known information
   You have to look at which information is covered in your model, are promotions not covered in your model then you have to take them into account separately.

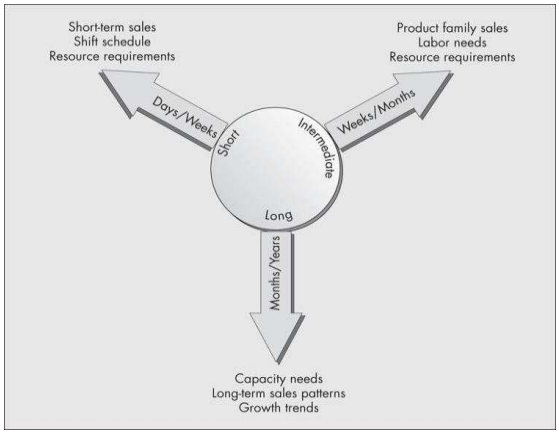
Elements of a good forecasts

A properly prepared forecast should fulfil certain requirements. The forecast should be:

- **Timely**. A certain amount of time is needed to respond to the information contained in a forecast. The forecasting horizon must cover the time necessary to implement possible changes.
- **Accurate**. This will enable users to plan for possible errors.
- **Reliable.** A technique that sometimes provides a good forecast and sometimes a poor will leave users with the uneasy feeling that some time soon they will get burned.
- **Expressed in meaningful units.** Financial planners need to know how many dollars will be needed, production planners need to know how many units, schedulers need to know the required machines and skills…
- **In writing.** It will increase the likelihood that everyone concerned is using the same information.
- **Simple to understand and use**. Simple technique enjoy widespread popularity because workers are more comfortable working with them.
- **Cost-effective.** Benefits should outweight costs.

To implement models also costs you something, so it could be that a very complex model makes better forecasts etc. but if it's much more expensive to implement then it's also not a good solution!

Forecasting horizons in operation planning



Short horizon: days/weeks

Intermediate horizon: weeks/ months

Long horizon: months/years

Forecast uses

Your forecast can be used to plan the system or your forecast can be used to plan how to use an already existing system.

- **Plan the system**

This generally involves **long-range plans** related to: types of products and services to offer, facility and equipment levels and facility location

- **Plan the use of the system**

This generally involves **short- and medium-range plans** related to: inventory management, workforce levels, purchasing, production, budgeting and scheduling

Steps in the forecasting process

1. **Determine the purpose of the forecast**. How will it be used, when will it be needed?
2. **Establish a time horizon**. It time indicate the time interval, keeping in mind that accuracy decreases when your interval gets longer.
3. **Obtain, clean, and analyze appropriate data.** Get rid of outliers and obviously incorrect data.
4. **Select a forecasting technique.**
5. **Make the forecast**
6. **Monitor the forecast errors.** This to determine if the forecast is performing in a satisfactory manner. If it is not, re-examine the method, assumptions, validity of data etc.

Evaluation of forecasts

Forecast accuracy and control

Because random variation is always present, there will always be some residual error. So it is important to include an **indication** of the extent to which the forecast might differ from the value of the variable that occurs.

Forecast error	Error = Actual - Forecast

Forecast errors should be **monitored**, if the errors fall beyond acceptable bounds, corrective action may be necessary. You must be aware of the errors that you make while forecasting, you have to follow up what happens with them.

Forecasts should also be **unbiased**: $E(error_t) = 0$

→ You can plot forecast errors over time to detect a bias *(see slide 10).*

The left side of the graph is an **unbiased** forecast, it will make mistakes but at least it will make mistakes above zero and it will make mistakes below zero. A **biased** forecast will make only positive or negative mistakes.

It's not a problem if you make errors while forecasting but it's not good if they are biased because then you're always overestimating or always underestimating. So a good model should be unbiased.

Measures of forecast accuracy:

MAD: **mean absolute deviation**. The average absolute forecast error. This weights all errors evenly.

$$\text{MAD} = \frac{\sum |\text{Actual}_t - \text{Forecast}_t|}{n}$$

MSE: **mean squared error**. Weights errors according to their squared values.

$$\text{MSE} = \frac{\sum(\text{Actual}_t - \text{Forecast}_t)^2}{n-1}$$

MAPE: mean absolute percent error. Weights errors according to a relative error.

$$\text{MAPE} = \frac{\sum \frac{|\text{Actual}_t - \text{Forecast}_t|}{\text{Actual}_t} \times 100}{n}$$

If you have different data sets: (10, 15, 12, 10, 11) and (1000, 1500, 1200, 1000, 1100)
→ the MAD and MSE will be much bigger for set 2 than for set 1 so you can't compare the two with each other
→ with the MAPE you can compare both data sets because it takes into account the **relative** size of the data

Qualitative forecasting methods

- **Qualitative methods**.

Consist mainly of subjective inputs. They permit the inclusion of ***soft*** information such as:
- human factors
- personal opinions
- hunches

→ These factors are difficult, or impossible to quantify.

- **Quantitative methods**.

Involve either the projection of historical data or the development of associative methods that attempt to use *causal variables* to make forecasts. These techniques rely on ***hard*** data.

Qualitative forecasts

Forecasts that use subjective inputs such as opinions from consumer surveys, sales staff, managers, executives and experts. This can happen when managers don't have enough time to gather and analyse quantitative data. Or when quantitative data is not yet available because we are taking about something new, or there is absence of historical data…

- **Executive opinions**
  A small group of upper-level managers meet and collectively develop a forecast. The advantage is that you bring together considerably knowledge and talent of various managers. But there is also the risk that the opinion of one managers will prevail.

- **Salesforce opinions**
  Members of the sales or customer service staff can be good sources of information due to their direct contact with customers and may be aware of plans customers may be considering for the future. But it is not always easy for them to make the distinction between what customers would *like* to do and what they actually *will* do in the future.

→ It's dangerous to work with forecasts based on sales force opinions when your sales people have incentives (e.g. they get extra money when they sell more than estimated). As a result they will underestimate the amount of sales so they will almost certainly obtain their bonus.

- **Consumer surveys**
  Since consumers ultimately determine demand, it makes sense to get input from them. These surveys typically represent a *sample* of consumer opinions. They advantage is that you can tap information which might not be available elsewhere. But it's not easy to make up such a survey and correctly administer the results.

- **Other approaches**
  Managers may obtain opinions from other managers or staff people or outside experts to help with developing a forecast. Also the **Delphi method** can be used, it is an iterative process intended to achieve a consensus.

Delphi method	An iterative process in which managers and staff complete a series of questionnaires, each developed from the previous questionnaire, to achieve a consensus for forecast.

People will not estimate the same numbers so how do you come to a consensus? **Step 1**: all individual experts are asked for their opinion 'Give me an estimate of sales' . **Step 2**: a group phase were all the experts will look at the estimated numbers. We let the outliers explain why they estimate such a high or low guess. After the discussion you do step 1 (the individual step) again and you will see that people change their opinions.

Time-series forecasts

Time-series forecasts are forecasts by **project patterns** identified in recent time-series observations.

Time-series	A time-ordered sequence of observations taken at regular intervals.

Forecasting techniques based on time-series data are made on the assumption that future values of the series can be estimated from past values of time-series. Analysis of time-series data requires the analyst to identify the **underlying behaviour** of the series:

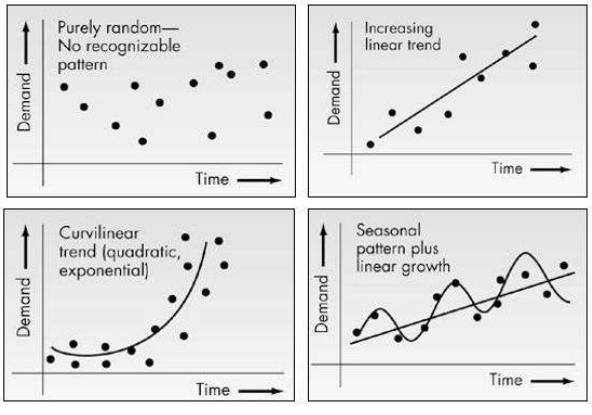
- **Trends**
  A long-term upward or downward movement in the data.
  → often due to: population shifts, changing incomes and cultural changes

- **Seasonality**
  Short-term fairly regular variations related to the calendar or time of day.
  → restaurants, theatres, hotels, … all seasonal demand

- **Cycles**
  Wavelike variations, lasting more than one year. "they have the same look as seasonality but the timing aspect is not so important, a top can be reached in winter but also again in summer so it's not linked to time!"
  → often related to: economic, political or agricultural decisions

- **Irregular variations**
  Caused by unusual circumstances, not reflective of typical behaviour. "Something happens and that will change my demand but that doesn't happen regularly. It's a unique event."
  → Severe weather conditions, labour strikes, major change in product or service etc.

- **Random variations**
  Residual variations after all other behaviours are accounted for. "The error that you have in your forecast is random variation because you will not be able to explain it."



Naïve methods

Naïve forecast	A forecast for any period that equals the previous period's actual value.

A naïve forecast uses a single previous value if a time series as the basis of a forecast. They can be used with:

- **A stable time series**: For your next forecast you estimate exactly the same value as the previous.
- **Seasonal variations:** Last period I had this value so for the upcoming period I will estimate the same value.
- **Trend**: The forecast is equal to the last value of the series, plus or minus the difference between the last two values of the series.

Techniques for averaging

These techniques work best when a series tends to vary about an average (stationary series), so when the datasets are quite **stable**.

Averaging techniques smooth variations in the data, because the individual highs and lows offset each other when they are combined into an average. They can also handle step changes or gradual changes in the level of the series.

There techniques that we will examine:

1) moving average
2) weighted moving average
3) exponential smoothing

MOVING AVERAGE

Moving average	Technique that averages a number of recent actual values, updated as new values become available.

A weakness of the naïve method is that the forecast just traces the actual data, with a lag of one period. But it does not smooth at all.

A moving average forecast averages a number of the most recent actual data values in generating a forecast.

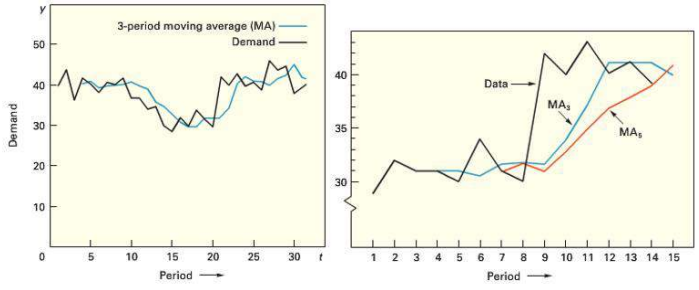
$$F_t = MA_n = \frac{\sum_{i=1}^{n} A^{t-1}}{n} = \frac{A_{t-n} + \cdots + A_{t-2} + A_{t-1}}{n}$$

F_t = Forecast for time period *t*
MA_n = *n* period moving average
A_{t-i} = Actual value in period t - i
n = Number of periods in the moving average

The moving average forecast **lags** behind the trend. The forecasted values are also much smoother than the actual values. The number of data points included in the average determines the model's sensitivity:

→ Fewer data points used-- more responsive
→ More data points used-- less responsive

The bigger the moving average the lower the curve, so it's less sensible.



ADVANTAGES	DISADVANTAGES
Easily understood	Lags behind a trend
Easily computable	Requires saving lots of past data points
Provides stable forecasts	Ignores complex relationships in data
	If there is a trend or seasonal effect you don't take it into account

WEIGHTED MOVING AVERAGE

Weighted moving average	More recent values in a series are given more weight in computing a forecast.

The weights must sum up to **1.00** (if it's lower you'll underestimate, if it's higher you'll overestimate). The heaviest weights are assigned the most recent values. The choice of weights is somewhat arbitrary and generally involves the use of trial and error to find a suitable weighting scheme.

$$F_t = w_{t-n}\,(A_{t-n}) + \ldots + w_{t-2}\,(A_{t-2}) + w_{t-1}\,(A_{t-1}) + \ldots + w_{t-n}\,(A_{t-n})$$

w_t = weight for period t, w_{t-1} = weight for period t -1, etc.
A_t = the actual value for period t, A_{t-1} = the actual value for period t -1, etc.

EXPONENTIAL SMOOTHING

Exponential smoothing	A weighted average method based on previous forecasts plus a percentage of the forecast error.

The forecast error is represented by (Actual – Previous forecast). The percentage of error is represented by α, this is also called the smoothing constant : $0 < \alpha \leq 1$

Next forecast = Previous forecast + α.(Actual – Previous forecast)

$$F_t = F_{t-1} + \alpha.(A_{t-1} - F_{t-1})$$

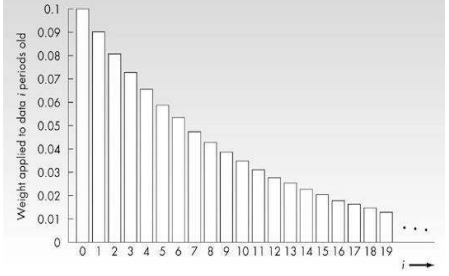
Smoothing:
if F_t is too high, e_t is positive, and the adjustment is to decrease the forecast
if F_t is too low, e_t is negative, and the adjustment is to increase the forecast

An alternative formula is:

$F_{t+1} = \alpha.A_{t-1} + (1 - \alpha).F_t$

$\Leftrightarrow F_{t+1} = \alpha.A_{t-1} + (1 - \alpha).(\alpha A_{t-1} + (1 - \alpha)F_t)$

Infinite expansion gives: $\mathbf{F_{t+1} = \sum_{i=0}^{\infty} \alpha\,(1-\alpha)^i \,.\, A_{t-i}}$



→A set of exponentially declining weights applied to past data

It is easy to show that the
sum of the weights $\sum_{i=0}^{\infty} \alpha\,(1-\alpha)^i = 1$

Effects of the value α on the forecast

- Small values of α: the forecasted value will be stable (show low variability)

Low α increases the lag of the forecast to the actual data if a trend is present

- Large values of α: the forecast will more closely track the actual time series (quick reaction to changes)

The smaller your alfa, the more you do smoothing BUT you lag behind in time (negative). People take alfa values that are rather low because they prefer stable forecasts. For production applications, stable demand forecasts are desired too. Therefore, a small α is recommended around 0.1 to 0.2 !

Comparison of moving average and exponential smoothing

SIMMILARITIES	DIFFERENCES
Both are appropriate for stationary series	ES carries all past history (forever!)
Both lag behind trend	MA eliminates bad data after N periods
Both depend on a single parameter	MA requires all N past data points to compute a new forecast estimate
For both methods multiple-step-ahead and one-step-ahead forecasts are identical	ES only requires the last forecast and the last observation of demand to continue

Trend-based methods

There are two important techniques that can be used to develop forecasts when a trend is present. One involves the use of a trend equation; the other is an extension of exponential smoothing.

LINEAR TREND

A simple data plot can reveal the existence and nature of a trend. A **linear trend equation** can develop forecasts when a trend is present.

Linear trend equation: $F_t = a + bt$

F_t = Forecast for period t
a = Value of F_t at t = 0
b = Slope of the line
t = Specified number of time periods from *t* = 0

You can also estimate the slope and the intercept from historical data:

- **The slope b** = $\frac{n\sum ty - \sum t \sum y}{n\sum t^2 - (\sum t)^2}$
- **The intercept a** = $\frac{\sum y - b\sum t}{n}$ or $\bar{y} - b\bar{t}$

With n the number of values and y the value of time series.

TREND-ADJUSTED EXPONENTIAL SMOOTHING

Trend-adjusted exponential smoothing	A variation of exponential smoothing used when a time series exhibits a linear trend.

It is also called **Double exponential smoothing** or **Holt's method**

→ The trend adjusted forecast consists of two components: a smoothed error + a trend factor.

$$TAF_{t+1} = S_t + T_t$$

With: S_t = previous forecast + smoothed error T_t = current trend estimate (= the trend)

This is a **one step ahead forecast** because you do + (1 x the trend).

$$TAF_{t+1} = S_t + T_t$$

$$\Leftrightarrow S_t = TAF_t + \alpha(A_t - TAF_t)$$

$$\Leftrightarrow T_t = T_{t-1} + \beta(TAF_t - TAF_{t-1} - T_{t-1})$$

α = smoothing constant for average
β = smoothing constant for trend

⚠ Trend-adjusted smoothing has the **ability to adjust to changes in trend**.

- We begin with an estimate of the intercept and slope at the start (e.g., by using linear regression).
- It's easier to calculate new forecasts by redefining the smoothing equations instead of a regression analysis.
- The smoothing constants may be the same, but often more stability is given to the slope estimate (more stability means a lower/smaller value so) $\beta \leq \alpha$

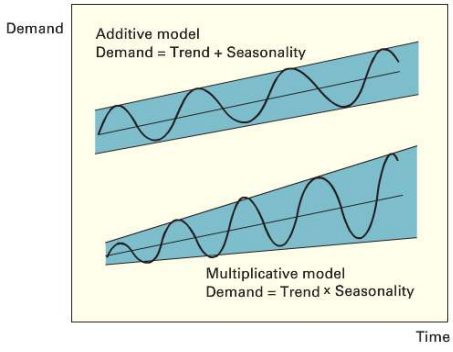
Methods for seasonal series

Seasonality	Regularly repeating movements in series values that can be tied to recurring events.

Seasonality in time series is expressed in terms of the amount that actual values deviate from the average value of a series. There are two different models of seasonality:

- **Additive**
  Seasonality is expressed as a quantity which is added to or subtracted from the series average in order to incorporate seasonality.

- **Multiplicative**
  Seasonality is expressed as a percentage of the average (or trend) amount which is then used to multiply the value of a series in order to incorporate seasonality.



SEASONAL RELATIVES

Seasonal relatives c_t = multiplicative seasonal factors	The seasonal percentage used in the **multiplicative seasonally** adjusted forecasting model.

Multiplicative seasonal factors or seasonal relatives: c_t (for $1 \leq t \leq N$)

→ where t=1 is first season of the cycle, t=2 is second season of the cycle, etc.

$$\sum c_t = N$$

⚠ *If for example, c_t = 1,25 then this implies a demand that is 25% higher than the baseline.*
Is, c_t = 0,75 then this implies a demand that is 25% lower than the baseline.

Seasonal relatives c_t are used in two different ways in forecasting. One way is to deseasonalize the data, the other way is to incorporate seasonality in a forecast.

- **Deseasonalize**= remove the seasonal component from the data to get a clearer picture of the nonseasonal components.
  → This is done by *diving each data point by its seasonal relative*.
- **Incorporating seasonality** = useful when demand has both trend and seasonal components
  → *obtain trend estimates for desired periods using a trend equation*
  → *add seasonality to the trend by multiplying the estimates by the corresponding seasonal relative.*

1) Computing seasonal relatives using the simple average method

Each seasonal relative is that season divided by the average of all seasons. There is no need to standardize the relatives when SA is used. It is a quick and dirty method of estimating seasonal factors.

- Step 1: compute seasonal averages
- Step 2: compute the overall average $\left(\frac{\textbf{sum of seasonal AVGs}}{\textbf{N}}\right)$
- Step 3: compute the SA relatives $\left(\frac{\textbf{seasonal AVG}}{\textbf{overall AVG}} = n\right)$

N = number of seasonal averages

→ $\sum n = N$

This method is fine if you have a seasonal effect but NO TREND, if you have a trend then this method doesn't work very well because it doesn't take trends into account.

2) Computing seasonal relatives using the centred moving average

Centred moving average	A moving average positioned at the centre of the data that were used to compute it.

This approach is slightly more complex but it accounts for any TREND that might be present in the data. See example on slides!

SEASONAL SERIES

To remove seasonality from a series, simply **divide each observation by the appropriate seasonal factor**. The resulting series will have no seasonality and may then be predicted using an appropriate method.

<> Once a forecast is made on the **deseasonalized series**, you then **multiply that forecast by the appropriate seasonal** factor to obtain a forecast for the original series.

What about new data?

Same problem prevails as before: updating is 'expensive'. As new data becomes available, we must start over to get seasonal factors, trend and intercept estimates. There is a method to smooth this seasonalized technique, it is called **Winter's Method or triple exponential smoothing.** BUT, defining and applying the method is outside the scope of this course…

Associative forecasting techniques

Associative techniques rely on the identification of related variables that can be used to predict values of the variable of interest. The essence of these techniques is the development of an equation that summarizes the effects of **predictor variables.**

Predictor variables	Variables that can be used to predict values of the variable of interest.

E.g.: *Home values may be related to such factors as home and property size, location, number of bedrooms, and number of bathrooms. Crop yields are related to soil conditions, amounts and timing of water, etc.*

SIMPLE LINEAR REGRESSION

Regression	A technique for fitting a line to a set of data points.

Simple linear regression is the simplest form of regression that involves a linear relationship between two variables.

The goal in simple linear regression is to obtain an equation of a straight line that minimizes the sum of squared vertical deviations from the line (i.e., the *least squares criterion*).

Least squares line: $\boldsymbol{y_c = a + bx}$

with: y_c = predicted (dependent) variable
x = predictor (independent) variable
b = slope of the line
a = value of y_c when $x = 0$ (i.e. the height of the line at the y intercept)

and $a = \frac{\sum y - b\sum x}{n} = \bar{y} - b\bar{t}$ $\quad$ $b = \frac{n\sum xy - \sum x \sum y}{n\sum x^2 - (\sum x)^2}$

with n = number of paired observations.

Forecasting in practise

Monitoring the forecast

Forecast errors are the rule rather than the exception, so there will be a succession of forecast errors. Tracking the forecast error and analysing them can provide useful insight on whether forecasts are performing satisfactory.

There are a variety of possible sources for forecast errors:

I. **The model may be inadequate due to:**
   a. Omission of an important variable
   b. A change or shift in the variable that the model cannot deal with
   c. The appearance of a new variable

II. **Irregular variations may occur**, due to changes in weather or other natural phenomena.

III. **Random variations**. There are always random variations!

You have to decide if forecast errors are random. If they are not random, it is necessary to investigate to determine which of the other sources is present and how to correct the problem. A useful tool for detecting nonrandomness in errors is a **control chart**.

Errors are plotted on the control chart in the order that they occur. The center line of the chart represents an error of zero. Then you have the upper and lower control limits who represent the upper and lower ends of the range of acceptable variation for the errors.

→ *all errors must be within the control limit*

→ *no patterns are allowed to be present. If there are then this is a **sign of nonrandomness**!*

Tracking signals can be used to detect forecast bias. To detect any bias in errors over time you have to figure out the tracking signal which can be done with the next formula:

$$\textbf{Tracking signal} = \frac{\sum(Actual_t - Forecast_t)}{MAD_t}$$

If you want to construct the **control chart** then 4 steps need to be followed:

1. Compute the MSE.
2. Estimate the standard deviation of the distribution of errors: s = MSE
3. Upper control line (UCL) : 0 + z.$\sqrt{\text{MSE}}$
4. LCL : 0 – z.$\sqrt{\text{MSE}}$ where z = Number of standard deviations from the mean

By making a control chart everything stays within its' borders. If your error is around zero, your model is unbiased (and that's where the zero comes from in the formulas as well).

Choosing a forecast technique

No single technique works best in every situation. When selecting a technique the manager must take a number of factors into consideration:

- The two most important factors are: **Cost** & **Accuracy**
- Availability of historical data, availability of forecasting software
- Time needed to gather and analyse data and prepare a forecast , forecast horizon, …

Operations strategy

The better forecasts are, the more able organizations will be to take advantage of future opportunities and reduce potential risks. A worthwhile strategy can be to work to **improve short-term forecasts**, if short term forecast are inaccurate why should people put faith in your long term forecasts?

Accurate up-to-date information on prices, demand and other important variables can have a significant impact on forecast accuracy. Also reduce the time horizon forecasts have to cover, forecasts over shorter timeframes are usually more accurate.

Sharing forecasts or demand data through the supply chain can improve forecast quality, resulting in lower costs and shorter lead time.

Strategic capacity planning

Capacity	The upper limit or ceiling on the load that an operation unit van handle

'Capacity needs' include:
- equipment
- space
- employee skills

In your company you will have to make a number of decisions that you cannot change after a couple of months (in the short run). For example the number of plants or the number of machines, these are big decisions that you make. And you can sell a machine if it turns out that you actually don't need it, but you won't be able to get all of your invested money back so it would be a waste.

On the other hand, if you build a plant that isn't large enough then you can enlarge it in the future but that will cost you time because a factory isn't built in two weeks.

Strategic planning capacity

The **GOAL** is to achieve a match between the long-term supply capabilities of an organization and the predicted level of long-term demand.
So it's very important that you do long-term planning, what can I do on the long-term and what do I expect to happen in the long-term? If you don't do your planning well then you'll be confronted with:

- **Overcapacity**: you involved costs but you're not doing anything with them, your operating costs are too high!
- **Undercapacity**: there might be some customer that you can't serve because your production can't follow the demand, there are strained resources and a possible loss of customers!

→ Both situations need to be avoided!

Capacity planning questions

There are **3 key questions** in capacity planning:
1) What kind of capacity is needed?
2) How much is needed to match demand?
3) When is it needed?

Aside from these 3 key questions are also a bunch of related questions: How much will it cost? What are the potential benefits and risks? Should capacity be changed all at once, or through several smaller changes? Can the supply chain handle the necessary changes?

Capacity also has a lot to do with **product design** and **production layout**! The machines you are using, how you are producing something, which resources are needed etc.

Capacity decisions are strategic, they influence several things :

1. They impact the ability of the organization to meet future demands
2. Affect operating costs
3. Are a major determinant of initial cost
4. Often involve long-term commitment of resources
5. Can affect competitiveness
6. Affect the ease of management
7. Have become more important and complex due to globalization
8. Need to be planned for in advance due to their consumption of financial and other resources

Defining and measuring capacity

You measure your capacity in units that **don't require to be updated**. It's not a good idea for example to measure your capacity in dollars, because the dollar value light change in a global market, but also your price might change. So it's not a good if you show your capacity in terms of dollars because that would require continuous updates…
Capacity can also be expressed by the number of inputs, so it's not only the outputs that can be used.

You have two useful definitions of capacity:

- **Design capacity**: what is given in the manual, in theory it could do that but in reality you see that the true values are actually a bit lower. Design capacity is the maximum output rate or service capacity an operation, process, or facility is designed for.

- **Effective capacity**: takes into account that you have some allowances. As well for machines as for people. Allowances are something normal, you can't change that… For example employees need to go to the toilet, they need to eat, take a break, … or maintenance for your machines.

Effective capacity = design capacity - allowances

Measuring system effectiveness

Actual output	The rate of output actually achieved, this cannot exceed effective capacity.

You don't only have allowances that you can foresee and control, you also have unexpected factors, outside of the control of managers. For example people that don't show up at work because they're not motivated, that is something that goes beyond your control as manager…

→ This causes that your actual output will be lower than your effective capacity!

- **Efficiency** = $\frac{\text{actual output}}{\text{effective capacity}}$

- **Utilization** = $\frac{\text{actual output}}{\text{design capacity}}$

Your efficiency can be quite high if you take a lot of allowances into account from the beginning. Because they you underestimate your effective capacity from the start, so it's normal that you will have a higher efficiency because you're not really working on your effective capacity. You influence the result. If you put your effective capacity already very low, then you'll have a bigger efficiency rate.

If your utilization percentage is much lower then, you'll notice that you've taken into account to many allowances because design capacity takes in none. Utilization gives the rate of what you actually do / what you can do in theory.

Determinants of effective capacity

- **Facilities**
- **Product and service factors**
- **Process factors**: *how productive is your production process?*
- **Human factors**: *Are they motivated your human factors? Are they always available?*
- **Policy factors**: *It might be that there's a policy that says that you aren't allowed to let your people do a lot of overtime, our unions, …*
- **Operational factors**: *you have to plan your system, make sure that you have enough people available at the right time to do the right work, do good inventory, if you don't have enough inventory then you can't do the necessary production*
- **Supply chain factors**: *Not only having the right capacity intern to your facility but also having a good supply chain is important*
- **External factors**: *for example environmental rules. It might be that you know one very effective way of producing but that this is too polluting and so you aren't allowed to use it*

Strategy formulation

Strategies are typically based on assumptions and predictions about:
- long-term demand patterns
- technological change
- competitor behaviour

When it comes to capacity, there are different **capacity strategies** where you can chose from:

1. **Leading**: build capacity in anticipation of future demand increases
2. **Following** : build capacity when demand exceeds current capacity
3. **Tracking** : similar to the following strategy, but adds capacity in relatively small increments to keep pace with increasing demand

→ Tracking is the same as following but here you implement your changes step by step. And not at once as you do by following.

Capacity Cushion	Extra capacity used to offset demand uncertainty

The capacity cushion strategy is that organizations that have greater demand uncertainty, typically have greater capacity cushion. While organizations with standard products and services generally have smaller capacity cushion because they don't need to worry about uncertainties.

"I will foresee that my demand will be a bit higher than normal so I'll have to produce more, I will need a higher capacity, but there is uncertainty so I have to take that into account. Maybe my demand won't be higher after all… "

There are **8 steps** in capacity planning:

1. Estimate future capacity requirements
2. Evaluate existing capacity and facilities; identify gaps
3. Identify alternatives for meeting requirements
4. Conduct financial analyses
5. Assess key qualitative issues
6. Select the best alternative for the long term
7. Implement alternative chosen
8. Monitor results

CALCULATING PROCESSING REQUIREMENTS

Calculating processing requirements requires reasonably accurate demand forecasts, standard processing times and available work time :

$$N_R = \frac{\sum_{i=1}^{k} p_i D_i}{T}$$

Where: N_R = number of required machines
p_i = standard processing time for product i
D_i = demand for product i during the planning horizon
T = processing time available during the planning horizon

If this formula gives you a number bigger than 1 it means that the process requires more than one machine!

SERVICE CAPACITY PLANNING

Service capacity planning can present a number of challenges related to:

- the need to be near the customer
- the inability to store services
- the degree of demand volatility

If you produce services you have an additional complexity, **you cannot store inventory**. You need to match supply with demand, when the customer is there you need to be able to give him what he asks for. If you don't have enough capacity at a certain point in time then waiting lines will occur.

To match supply with demand you can use **three types of buffers**:

- **Buffering with time**: let them wait until you have enough capacity to serve them
- **Buffering with inventory**: build an inventory so you can give your customers immediately what they ask for (this is not possible with services)
- **Buffering with capacity**: if you build more capacity then you can decrease your waiting lines

There are also certain **strategies** that are used to offset your capacity limitations and that are intended to achieve a closer match between supply and demand = **demand management strategies**

→ Pricing, promotions, discounts or other tactics that shifts demand from peak periods

By using pricing, promotions and discounts you can balance your demand.
Example: costumes are only bought during carnival, but if you give a lot of discounts on your costumes during periods that are far away from carnival you will continue to have some demand + the demand during the carnival won't be so high anymore. So your stocks don't need to be that big.

If you have **seasonality** and you want to balance it then you can use discounts and promotions, that's is good strategy to follow. But **if you don't have seasonality** and you use promotions and discount then that can be counterproductive, because it won't give you a stable demand. At the moment of the promotion your demand will, all of a sudden, be a lot higher.

In-house or outsourced?

Once your capacity requirements are determined, the organization must decide whether to produce a good service itself or to outsource. When thinking about outsourcing you have to consider several factors: -*What capacity do I have available ?*

-*Do I have the necessary expertise, where can I find the necessary expertise ?*

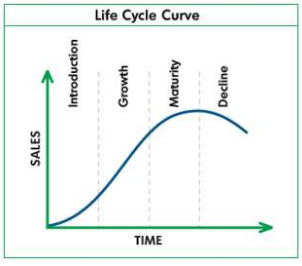
- *Will the quality be good if I outsource ?*
- *What is the nature of my demand ?*
- *What are the costs of outsourcing and what are the risks ?*

Developing capacity alternatives

1. **Design flexibility into systems**

At the beginning you can build enough capacity and build your factory on a ground that allows to extend it later. But eventually you don't know if your company, after growing, will grow even more or stabilize. So you have to take into account that it's possible that your company will expand further.

2. **Take the stage of the life cycle into account**



You know that, at the end of your lifecycle, when you go down you don't have to expect to rise again. Then it's actually more likely that you will shrink, so you know you won't need to expand anymore.

You kind of know what will come and this is good!

3. **Take a 'big-picture' approach to capacity changes**

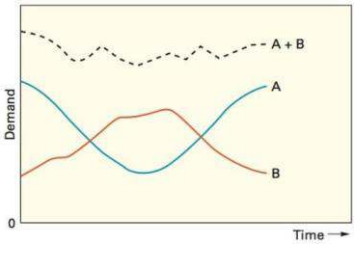
Do NOT look at your single operations while trying to optimise them all separately. What you need to know is what the **bottleneck** of your operations is. If you improve the first 4 operations then you'll still have a problem at your bottle neck so that won't help! You have to look at your **bottleneck operation!**

4. **Prepare to deal with capacity 'chunks'**

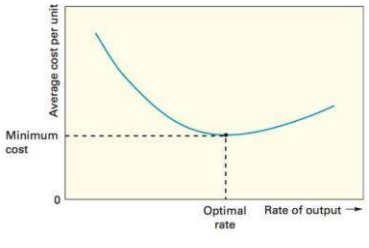
Capacity chunks are small incremental changes. Don't try to change everything at once, it will be more difficult to implement these huge changes and it might confuse your employees too. Make changes in small steps, so you can figure out what works best for you.

5. **Attempt to smooth capacity requirements**

You can try to put A and B together on a production line because, as you can see in the graph, your demand will be more stable over time and you won't have to deal with all the peaks. Because a peak in line B will be stabilised by a lower demand of product A.

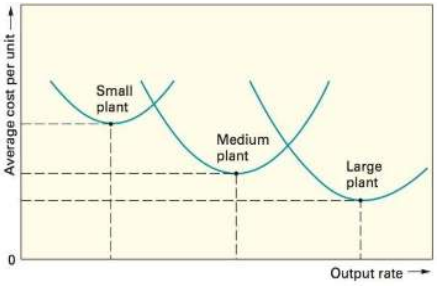


6. **Identify the optimal operating level**



→ If you produce less than the optimal level, you'll pay more per unit because you aren't using your full potential capacity! **Economies of scale**

Each of the plants have a certain optimal production level, at a certain point in time it's wise to start shifting from one plant to another



Diseconomies of scale →

Economies of Scale	If output rate is less than the optimal level, increasing the output rate results in decreasing average per unit costs.

Reasons for economies of scale:

- Fixed costs are spread over a larger number of units
- Construction costs increase at a decreasing rate as facility size increases
- Processing costs decrease due to standardization

Diseconomies of Scale	If the output rate is more than the optimal level, increasing the output rate results in increasing average per unit costs.

Reasons for diseconomies of scale

- Distribution costs increase due to traffic congestion and shipping from a centralized facility rather than multiple smaller facilities
- Complexity increases costs
- Inflexibility can be an issue
- Additional levels of bureaucracy

7. **Choose a strategy if expansion is involved**

Constraint management

Constraint management has to do with the bottle neck operation, one operation that limits the performance of a process or system in achieving its goals.

Constraint	Something that limits the performance of a process or system in achieving its goals

You have different categories of constraints: market, resource, material, financial, knowledge, policy…

Now how can you resolve your constraint issues?

1) Identify the most pressing constraint
2) Change this operation to achieve maximum benefit, given the constraint
3) Make sure other portions of the process are supportive of the constraint
4) Explore and evaluate ways to overcome the constraint
5) Repeat the process until the constraint levels are at acceptable levels

Do you have a bottleneck? → Use constraint management!

Evaluating alternatives

Alternatives should be evaluated from different perspectives, **economic and non-economic.** (slides)
To do that there are different techniques, the most important one is the **cost-volume analysis**.
But there are also others like financial analysis, decision theory, waiting-line analysis, etc.

COST-VOLUME ANALYSIS

"The cost-volume analysis focusses on the relationship between cost, revenue and volume of the output."

You have:

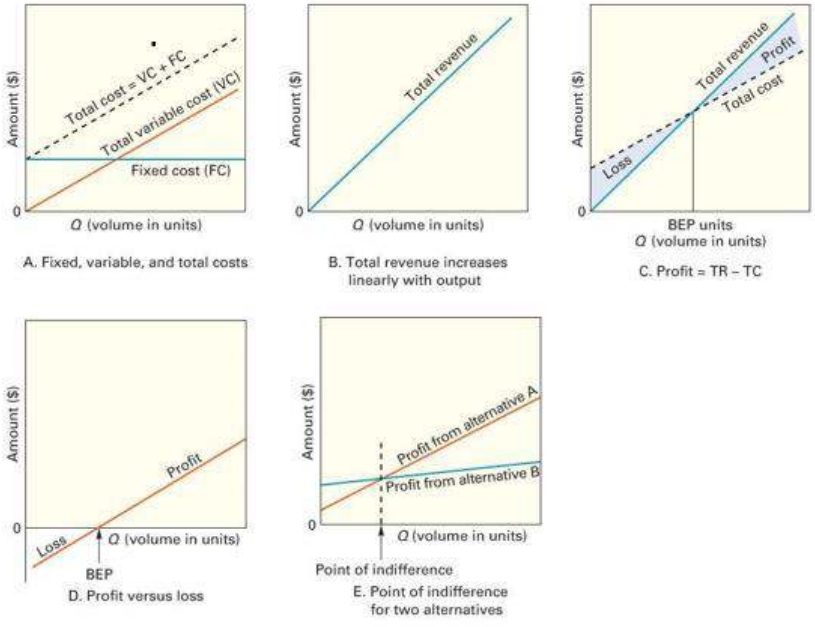
- **Fixed costs** (FC): they remain constant regardless of output volume
- **Variable costs** (VC): they vary directly with the volume of output → **Quantity (Q) x cost per unit (v)**
- **Total cost** (TC): FC + VC
- **Total revenue** (TR): revenue per unit (R) x Quantity (Q)
-

Break-even Point (BEP)	The volume of output at which total cost and total revenue are equal.

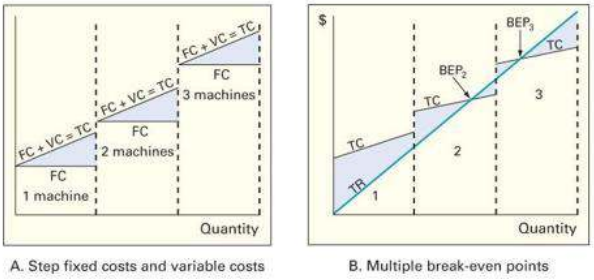
Profit (P) = TR – TC = (R x Q) – [(Q x v) + FC] = [Q x (R – v)] – FC

$$\mathbf{Q_{BEP}} = \frac{FC}{R-v}$$

→ **COST-VOLUME RELATIONSHIPS**



Capacity alternatives may involve **step costs,** which are costs that increase stepwise as potential volume increases. The implication of such a situation is the possible occurrence of **multiple break-even quantities**.



Cost-volume analysis is a viable tool for comparing capacity alternatives if certain assumptions are satisfied:

- **One product** is involved
- Everything produced can be **sold**
- The **variable cost per unit is the same** regardless of volume
- **Fixed costs do not change** with volume changes, or they are step changes
- The **revenue per unit is the same** regardless of volume
- Revenue per unit > variable cost per unit

Capacity planning strategically **impacts all areas of the organization**:

- It determines the conditions under which operations will have to function
- **Flexibility** allows an organization to move quickly and easily
  - It reduces the organization's dependence on forecast accuracy and reliability
  - Many organizations utilize capacity cushions to achieve flexibility
- **Bottleneck management** is one way by which organizations can enhance their effective capacities
- **Capacity expansion strategies** are important organizational considerations:
  - Expand-early strategy
  - Wait-and-see strategy
- Capacity contraction is sometimes necessary
  - Capacity disposal strategies become important under these conditions

Process selection and facility layout

Process selection

Process selection	Refers to deciding on the way production of goods or services will be organized.

Process selection has major implications for capacity planning (Chapter 3), layout of facilities, equipment and design of work systems.

Process strategy

There are **two key aspects** of process strategy:

- **Capital intensity**: the mix of equipment and labour that will be used by the organization
- **Process flexibility**: the degree to which the system can be adjusted to changes in processing requirements due to such factors as:
  - Product and service design changes
  - Volume changes
  - Changes in technology

Process selection

In process selection there are **two key questions**:

- How much variety will the process need to be able to handle?
- How much volume will the process need to be able to handle?

Product or Service and Flexibility Variety and Equipment Flexibility

	High	Moderate	Low	Very low
Low or very low volume	**Job Shop** repair shop emergency room			
Moderate volume		**Batch** commercial bakery classroom lecture		
High volume			**Repetitive** assembly line automatic car wash	
Very high volume				**Continuous Flow** petroleum refining water treatment

There are 4 main process types:

- **Job shop**: you can produce very different product types.
- **Batch**: you can produce a variety of products, but the variety is a bit lower than in a job shop (because you don't produce products separately but in batch).
- **Repetitive**: low product variety.
- **Continuous flow**: only one product type but you can produce it in very high volumes and continuously.

	Job Shop	Batch	Repetitive/ Assembly	Continuous
Description	Customized goods or services	Semi-standardized goods or services	Standardized goods or services	Highly standardized goods or services
Advantages	Able to handle a wide variety of work	Flexibility; easy to add or change products or services	Low unit cost, high volume, efficient	Very efficient, very high volume
Disadvantages	Slow, high cost per unit, complex planning and scheduling	Moderate cost per unit, moderate scheduling complexity	Low flexibility, high cost of downtime	Very rigid, lack of variety, costly to change, very high cost of downtime

→ The more you go to the right in the table above, the lower your costs per unit get.
→ Some situations are of limited duration, other situations are ongoing.

Project	A project is used for work that is **nonroutine**, with a unique set of objectives to be accomplished in a limited time frame.

There is also an increasing pressure for organizations to operate **sustainable production processes**. Sustainable production is the creation of goods and services using processes and systems that are: non-polluting, conserving of energy and natural resources, economically efficient, safe and healthful for workers, communities and consumers.

Process and information technology

Process and information technology can have a major impact on costs, productivity and competitiveness. You have two types of technology:

- **Process technology**: methods, procedures and equipment used to produce goods and provide services
- **Information technology**: the science and use of computers and other electronic equipment to store, process and send information.

Automation

Automation means that machinery has **sensing and control devices** that enable it to operate automatically. It can be very interesting to automate your process but it can cost you a lot of money as well. And maybe your automation can't deal with market changes.

→ Automation is very rigid, you have to take that into account when thinking about adopting it.

- **Fixed automation**: high-cost, specialized equipment for a fixed sequence of operations.
- **Programmable automation**: high-cost, general-purpose equipment controlled by a computer program that provides both the sequence of operations and specific details about each operation.
- **Flexible automation**: evolved from programable automation. It uses equipment that is more customized than that of programmable automation. A key difference between the two is that flexible automation requires significantly less changeover time!

Robots are an example of programmable automation, it's also high cost machinery but you can change the settings. The problem with programmable automation is that you need very skilled people who can program your machinery into doing what you want it to do.
Flexible automation means that you are going to buy equipment that is a bit **customized** to what we want to do so we don't have to program everything ourselves, but the machine is already programmed for us.

Facilities layout

Layout	The configuration of departments, work centres and equipment with particular emphasis on movement of work (customers or materials) through the system.

Facility layout decisions arise when you design new facilities or when you want to re-design existing ones. **Problems** with the facility layout can occur in several organisations: *hospitals, warehouses, schools, offices, workstations, banks, shopping centres, airports, industrial plants, …*

→ It's very important that you fix these problems if you want your organisations to be efficient!

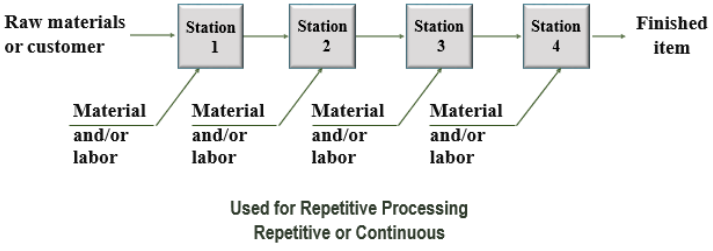
There are some **layout design objectives** as well.
First of all you have the **basic objective**: facilitate a smooth flow of work, material and information through the system. Then you have some **supporting objectives:**

1) Facilitate product or service quality
2) Use workers and space efficiently
3) Avoid bottlenecks
4) Minimize material handling costs
5) Eliminate unnecessary movement of workers or material
6) Minimize production time or customer service time
7) Design for safety

Furthermore there are four basic layout types:
- Product layouts
- Process layouts
- Fixed-Position layouts
- Hybrid layouts

Product layout

A product layout is a layout that uses standardized processing operations to a achieve smooth, rapid, high-volume flow. The resources are organized in order to create optimal flow from one operation to the next.



It's really specialised machinery that you put in a certain order, and the machines are only used to produce one specific type of products.

Product Layout is good when there is a limited range of high quantity (not quality!) products. Because:

- Because it's highly capital intensive and not work intensive since there are reduced material handling costs.
- There is little work-in-process inventory and short lead times
- There are **dedicated production** lines for very high runners
- There are production lines per product family for B products.

Overall it offers **low flexibility but high efficiency**!

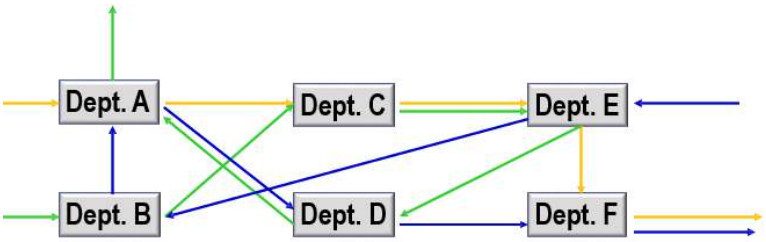
Advantages	Disadvantages
• High rate of output • Low unit cost • Labor specialization • Low material handling cost per unit • High utilization of labor and equipment • Established routing and scheduling • Routine accounting, purchasing, and inventory control	• Creates dull, repetitive jobs • Poorly skilled workers may not maintain equipment or quality of output • Fairly inflexible to changes in volume or product or process design • Highly susceptible to shutdowns • Preventive maintenance, capacity for quick repair and spare-parts inventories are necessary expenses • Individual incentive plans are impractical

Labor specialization: If you have a product layout then at every station the same task has to be done over and over again which results in low training costs → cheap labour.

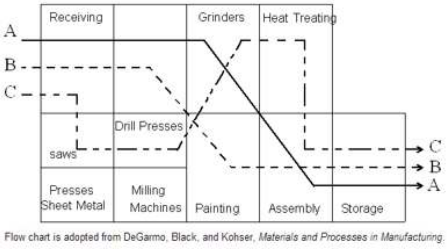
But if something happens at station 3 then your entire line will be influenced, because station 4 won't get its input and station 2 will be stuck because they can't hand their output to the next station…

Process layout

Process layouts are layouts that can handle varied processing requirements.



Used for Intermittent processing
Job Shop or Batch



Flow chart is adopted from DeGarmo, Black, and Kohser, *Materials and Processes in Manufacturing*

Group all the machines of a certain type together and let the product travel through your factory. But that's not so efficient because your products might have to cross big distances when they go from one group to the other. Though it's more efficient in a way that you don't have to put the same machines at different spots in your production line.

Process orientated production is good when you have many low quantity products, because:

- You have general-purpose machinery
- Reduced capital intensity but high work intensity due to higher material handling costs
- Production in **batches**: work-in-process inventory and lead times increase

Overall it offers **high flexibility but low efficiency**!

Advantages	Disadvantages
• Can handle a variety of processing requirements • Not particularly vulnerable to equipment failures • General-purpose equipment is often less costly and easier and less costly to maintain • It is possible to use individual incentive systems	• In-process inventories can be high • Routing and scheduling pose continual challenges • Equipment utilization rates are low • Material handling is slow and inefficient • Reduced spans of supervision • Special attention necessary for each product or customer • Accounting, inventory control, and purchasing are more involved

Fixed-position layout

A fixed-position layout is a layout in which the product or project remains stationary, and workers, materials and equipment are moved as needed.

→ You go to the spot where something has to be produced, for example when building a house.

Hybrid layouts

Some operational environments use a combination of the three basic layout types.

For example: hospitals, supermarkets, shipyards, …

And some organisations are moving away from process layouts in an effort to capture the benefits of product layouts:

- **Cellular manufacturing**: Productfamily per productfamily instead of product per product.
- **Flexible manufacturing systems:** They add some degree of automatization but the flexible type, not the high degree programmable one.

Cellular layouts

A cellular layout is a layout in which workstations are grouped into a cell that can process items that have similar processing requirements.

→ Groupings are determined by the operations needed to perform the work for a set of similar items, part families, that require similar processing.

→ The cells become miniature versions of product layouts.

Group techonology	The grouping into part families of items with similar design or manufacturing characteristics. This requires a systematic analysis of parts to identify the part families.

The design characteristics are: size, shape and function.

The manufacturing or processing characteristics are: Type of operations required and Sequence of operations required

Service layout

Service layouts can be categorized as: product, process, or fixed position.

→ Service layout requirements are somewhat different due to such factors as:

- Degree of customer contact
- Degree of customization

Common service layouts are: Warehouse and storage layouts, Retail layouts and Office layouts

You well have to take into account special things when you design a **service layout**, because services can only be 'delivered' when you are with the customer. It's not in a fixed facility.

Designing Product layouts: line balancing

⚠ The **goal** of a product layout is to arrange workers or machines in the sequence that operations need to be performed!

Line balancing is the process of assigning tasks to workstations in such a way that the workstations have approximately equal time requirements.

→ You split up your entire process in several small parts (A, B, C, D, …) and you call them **workstations.**

GOAL: Obtain task grouping that represents approximately equal time requirements since this minimizes idle time along the line and results in a high utilization of equipment and labour.

Why is line balancing important?

1) It allows us to use labour and equipment more efficiently.
2) To avoid fairness issues that arise when one workstation must work harder than another.

Cycle time

Cycle time	The maximum time allowed at each workstation to complete its set of tasks on a unit.

Cycle time also establishes the **output rate** of a line:

$$\textbf{Cycle time} = \frac{\text{operating time per day}}{\text{desired output rate}}$$

$$\textbf{Output rate} = \frac{\text{operating time per day}}{\text{cycle time}}$$

Desired output rate = demand rate → what is needed by the market

⚠ The desired output rate is the number of products that you wish to produce → this decides how many workstations you will need!

Assembly line configuration	Grouping tasks together and assigning them to workstations.
Cycle time 'c'	The time between the completion of two consecutive products
Takt time (takt-cycle time)	$\frac{\text{Available production time per day}}{\text{total demand per day}}$ = T/d

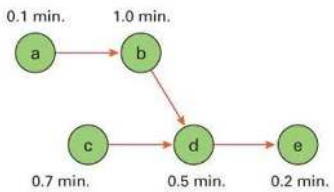
You have a set of elementary operations (tasks) {1, 2, 3, …, k} with all their own **task times t_k** .

The number of work stations is not defined in the beginning, you only know that you want to divide your work over workstations. But how do you know how many workstations are needed?

→ The required number of workstations is a function of the desired output rate and our ability to combine tasks into a workstation. You can calculate the minimum requirement of workstations:

$$\mathbf{N_{min}} = \frac{\sum t}{\text{Cycle time}}$$

Met N_{min} = theoretical minimum number of stations
$\sum t$ = Sum of tasks



Precedence diagram	A diagram that shows elemental tasks and their precedence requirements.

Assigning tasks to workstations

You can assign tasks in order of ***most following tasks***: count the number of tasks that follow.
Or you can assign tasks in order of ***greatest positional weight***: Positional weight is the sum of each task's time and the times of all following tasks.

METHOD:

1. Assign a numeric score **n(x)** to every task
2. Update the set of eligible tasks; i.e. tasks for which the immediate predecessors are assigned
3. Assign the task with the **highest score** to the first station for which nor the capacity constraints, nor the precedence constraints are exceeded. Go back to step 2.

Measuring effectiveness

- **Balanced delay** (percentage of idle time of a line)

$$\textbf{Balance Delay} = \frac{\text{Idle time per cycle}}{N_{actual} \text{ x Cycle time}} \text{ x } 100$$

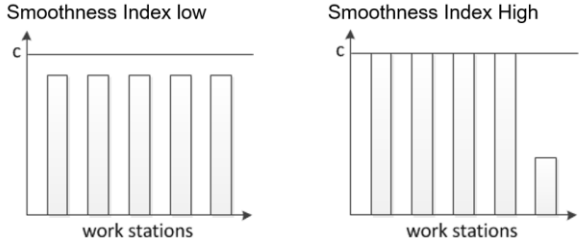
N_{actual} is the actual number of workstations

- **Efficiency** (percentage of busy time of a line)

Efficiency = 100% - Balance Delay

- **Smoothness Index** (to indicate the relative smoothness of a given line balance. A smoothness index of zero indicates perfect balance.)

$$\textbf{Smoothness index} = \sqrt{\sum_{i=1}^{n}(\text{maximum station time} - \text{station time}_i)^2}$$



Feasible line balance	Assignment of each task to a station such that the precedence constraints and further restrictions are fulfilled.

General assembly line balancing (GALB)

Until now, our focus was on the **simple assembly line balancing problem (SALBP**):

- This considers a single, straight assembly line used for only one type of product (single model)
- The task times are deterministic
- The only assignment constraint is the precedence relationship between tasks (visualized by a precedence graph)
- All workstations are equally equipped and prepared to perform tasks

But the **general assembly line balancing problem (GALBP)** integrates more practice relevant aspects:

- Stochastic task times
- Multi/mixed-model lines
- Processing alternatives
- Additional constraints
- Time and space constrained ALB
- …

Assembly line balancing is a very broad field of research. There are many variants of ALB problems that have been researched, but many research challenges remained. There still exists a gap between research and practice.

Designing process layouts

The main issue in designing process layouts concerns **the relative placement of the departments**.
A major objective in designing process layouts is to minimize transportation cost, distance, or time and this can be done by **measuring effectiveness.**

<u>The information requirements for designing a process layout are:</u>

1. A list of departments to be arranged and their dimensions
2. A projection of future work flows between the pairs of work centres
3. The distance between locations and the cost per unit of distance to move loads between them
4. The amount of money to be invested in the layout
5. A list of any special considerations
6. The location of key utilities, access and exit points, etc.

From-to charts

From-to charts can show you:

- The distances, separating pairs of work centres
- The numbers of materials handling trips between pairs of work centres
- Materials handling costs between pairs of work centres

'From-to' charts are a bit similar to mileage charts on roadmaps.

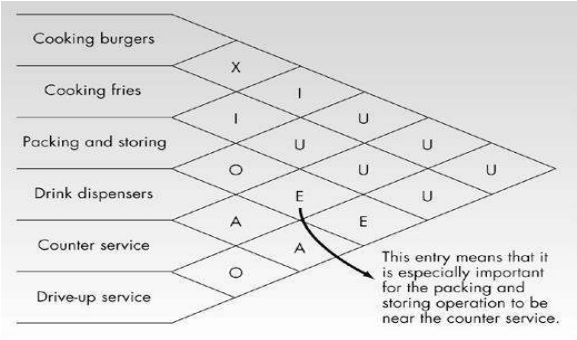
Process layout problems

→ See slides

Activity relationship chart

Each pair of operations is given a letter to indicate the **desirability of locating the operations near each other**. The letter codes for closeness ratings are:

A: Absolutely necessary
E: Especially important
I: Important
O: Ordinary importance
U: Unimportant
X: Undesirable



Location planning and analysis

Introduction to location decisions

Location decisions are made for a variety of reasons. Some firms view the location as a part of their marketing strategy, and they look for locations that will help them to expand their markets. These locations decisions reflect the **addition of new locations to an existing system**. This also occurs when are organization experiences a growth in demand that cannot be satisfied by expansion at an existing location.

Some firms face location decisions through **depletion of basic inputs** (e.g. fishing, you need to relocate due to the exhaustion of fish). Also **a shift in markets** can cause you to consider relocation. Or when **the costs of doing business at a certain location** reach a point where other locations begin to look more attractive.

The nature of location decisions

Strategic importance

Location decisions are strategically important since:

- They are closely tied to an organization's strategy
  - That strategy can be **low cost** *(e.g. relocate to where labour is cheap, close to raw materials)*
  - Or convenience to attract market share
- They effect capacity and flexibility
  Some locations may be subject to space constraints that limit future expansion, or restrict the types of products or services that can be offered…
- They represent a long-term commitment of resources.
- They effect investment requirements, operating costs, revenues, and operations
  Poor location decisions can result in excessive transportation costs, loss of competitive advantage, a shortage of qualified labour, inadequate supplies of raw materials, etc.
- Impact competitive advantage
- Importance to supply chains

Location **decisions** are based on profit potential or a balance between cost and customer service. The idea is that you find a number of *acceptable* locations from which you have to choose. The position in the supply chain plays a major role in deciding.

→ At the end: accessibility, consumer demographics, traffic patterns, and local customs are important
→ In the middle: a location near suppliers or markets is desirable
→ At the beginning: a location near the source of raw materials is good

Supply chain considerations

The supply chain must address supply chain **configuration**. This includes determining the number of suppliers and their location, idem for production facilities, warehouses and distribution centres.

A related issue is whether to have **centralized** or. **decentralized distribution**.

> ***Centralized*** *means that you have one distribution centre from where you will ship everything, this yields scale economies but it might give you higher transportation costs.*
> ***Decentralized*** *means that you have more than one distribution centre, depending on location or other factors. It's more responsive to local needs.*

The importance of such decisions is underscored by their reflection of the basic strategy for accessing customer markets → a significant impact on costs, revenues and responsiveness.

Location options

Existing companies generally have four options available in location planning:

1. Expand an existing facility
   → attractive if there is adequate room
2. Add new locations while retaining existing facilities
   → essential to take the impact on the total system into account
3. Shut down one location and move to another
4. Do nothing (if there are no benefits)

Global locations

Many organisations are outsourcing operations to other companies on foreign locations. Companies are finding strategic and tactical reasons to globalize their operations.

Facilitating factors

Two key factors have contributed to the attractiveness of globalization:

- Trade agreements, barriers to international trade such as tariffs and quotas have been reduced with trade agreements such as: NAFTA, GATT, .S.-China Trade Relations Act, EU and WTO efforts to facilitate trade.

- Technology: advances in communication and information technology lead to more globalization

ADVANTAGES: A wide range of benefits have been collected by organizations that have globalized operations: First of all you can enter **new markets** and increase your sales. Globalization can help your company to **save costs**, you can operate more closely to your customers, you can make use of cheaper labour forces etc. Advantages can be found in **different legal rules and regulations** as well, when you can offer lower wages for longer work days, or more favourable liabilities etc. **Financially** globalization might be a good idea as well, to impact currency changes. But there are many **other reasons**.

DISADVANTAGES: However there are a number of disadvantages that may arise when locating globally. You might face **high transportation and security costs**, due to poor infrastructure and theft. Plus security at international borders can slow down shipment. If you produce something abroad then you still have to get it back here to sell it, in this process you can be confronted with **import restrictions**. **Locating out-of-country** can raise some **criticism** from buyers: cheap clothing stores (Primark), usually use cheap labour forces that are not ethical (SWEATSHOP). Also in the car industry, (they start new facilities in China and then they ask people from here to go work there and help build up the facilities) you can get criticised on that. Factories and facilities will go away in Belgium, this creates a lot of unemployment here. **Unskilled labour**, plus the work ethic may differ from the one at home.

RISKS: organizations locating globally should be aware of potential risk factors that are related to political instability and political unrest, terrorism, economic instability (inflation, deflation), legal regulation, ethical considerations and cultural differences.

Managing global operations:

There are some managerial implications for global operations:

- **Language and cultural differences**: due to the differences in language there is a high risk of miscommunicating. When you can't or barely understand each other this might impact the development of trust. Cultural differences on the other hand can create different management styles and some employees might find it difficult to deal with that. Also, in some cultures they are used to corruption and bribery when doing business while that certainly isn't the case for all!

- **Increased travel (and related) costs**: if you have many facilities across the globe than you can't run them all from in one place. You will have to travel around to go and have a look at the situation there. Or you can empower other managers to look after the facilities in your place. But then still you will all need to get together at one point for a meeting etc.

- **Challenges associated with managing far-flung operations**: managers may have to deal with corruption and bribery as well as differences in work ethics.

- **Level of technology and resistance to technological change**: some countries are technological more behind then others and not all of them are willing to implement the newest technologies.

- **Domestic personnel may resist locating, even temporarily**: it might be that you have a very good employee, so good that you want him to travel abroad and make international facilities great as well. However not all employees are willing to relocated abroad, certainly not when they have a family etc.

General procedure for making location decisions

Following steps need to be followed:

1. Decide on the **criteria** to use for evaluating location alternatives
2. Identify **important factors**, such as location of markets or raw materials
3. Develop **location alternatives**
    a. Identify the country or countries for location
    b. Identify the general region for location
    c. Identify a small number of community alternatives
    d. Identify the site alternatives among the community alternatives
4. Evaluate the alternatives and make a **decision**

(see the figure on slide 15)

Identifying a region

In a country you can look for specific region. Sometimes you are looking for specific things that are valuable for your company, and they might be linked more to a certain region than to another. When you are trying to identify a region you have to take into account some primary regional factors:

- **Locations of raw materials**
    → Necessity: if you're in the fishing, agriculture, mining industry, … then it's a necessity to be near your raw materials.
    → Perishability: if you are in the food industry then it's also crucial to be close to your raw materials because they have to be fresh, certainly if your food is likely to go bad quickly.
    → Transportation costs: if it's too expensive to transport then you better locate close to them.

- **Location of markets**
  - → As part of a profit-oriented company's competitive strategy, they locate near the market they intend to serve (Plus low costs thanks to cheap, unskilled labour, less regulations, …)
  - → So not-for-profits can meet the needs of their service users
  - → Due to distribution costs and perishability is can be desirable to be close to the market

- **Labour forces**
  - → Cost of labour (important for labour-intensive organisations)
  - → Availability of suitably skilled workers
  - → Wage rates in the area
  - → Labour productivity
  - → Attitudes toward work (concerning absenteeism and similar factors)
  - → Whether unions pose a serious potential problem

- **Other factors**
  - → Climate and taxes may play an important role in location decisions.
    For example if you have a region with a very bad climate then that can influence your organisation. A lot of snow can cause difficulties with transportation and your employees coming to work.

Identifying a community

Many communities actively attempt to attract new businesses if they perceive them to be a good fit for the community. Businesses, on the other hand, also actively seek attractive communities based on factors such as: *quality of life, services, attitudes, taxes, environmental regulations, utilities, development support, …*

Identifying a site

Primary site considerations are:- land
- transportation
- zoning
- other restrictions

Multiple plant manufacturing strategies

When you have multiple plants you need to think about what strategy you will use to organize all the different operations in your plants:

- **Product plant strategy**

Entire products or product lines are produced in separate plants, and each plant usually supplies the entire domestic market. This is essentially a decentralized approach.

- **Market area plant strategy**

Plants are designed to serve a particular geographic segment of the market. It's also possible that the plants produce most, if not all, of a company's products. Significant savings on transportation can be made. This approach requires centralized coordination of decisions.

- **Process plant strategy**

Different plants focus on different aspects of process (e.g. automobile manufacturers – engine plants, body stamping plants, etc.). But here the coordination across the system becomes a significant issue!

- **General-purpose plant strategy**

Plants are flexible and capable of handling a range of products.

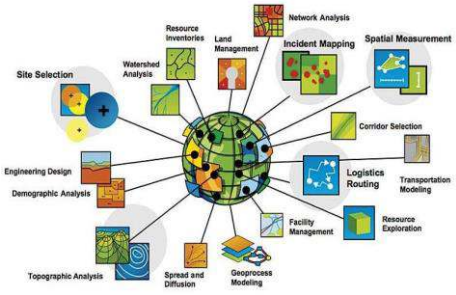
Geographic information systems

GIS	A computer based tool for collecting, storing, retrieving, and displaying demographic data on maps.

For location analysis a GIS makes it relatively easy to obtain detailed information on factors such as age, population density, income, traffic patterns, utilities, shopping centres, crime rates etc.

Geographical information systems aid decision makers in:
- targeting market segments
- identifying locations relative to their market potential
- planning distribution networks

Plus, portraying relevant information on a map makes it easier for decision makers to understand.



Service and retail locations

Some things need to be considered when talking about service and retail locations:

- **Customer access** is the prime consideration for some businesses (hotels, restaurants, banks etc.). For others (like service call centres, catalog sales) it's not so important.
- Nearness to raw materials is usually not a consideration here.
- Most considerations tend to be profit or revenue driven, and are concerned with demographics, competition, traffic volume patterns and convenience.
- **Clustering**: similar types of business locate near one another.
  (e.g. medical services or doctors are located near hospitals)

Manufacturing/Distribution	Service/Retail
Cost focus	**Revenue focus**
Transportation modes/costs	Demographics: age, income, education
Energy availability/costs	Population/drawing area
Labor cost/availability/skills	Competition
Building/leasing costs	Traffic volume/patterns
	Customer access/parking

A comparison of service/retail considerations and manufacturing considerations

Evaluating location alternatives

Common techniques to evaluate location alternatives are:

I. Locational cost-volume-profit analysis
II. Factor rating
III. Transportation model
IV. Centre of gravity method

I. Locational cost-volume-profit analysis

This is a technique for evaluating location choices in economic terms.

STEPS: 1) determine the fixed and variable costs for each alternative

2) plot the total-cost lines for all alternatives on the same graph

3) determine the location that will have the lowest total cost (/ highest profit) for the expected level of output.

To compute the total cost for each alternative location :

Total Cost = FC + *v* x *Q*

where: FC = Fixed cost
v = Variable cost per unit
Q = Quantity or volume of output

There are some assumptions with this technique:

- Fixed costs are constant for the range of probable output
- Variable costs are linear for the range of probable output
- The required level of output can be closely estimated
- Only one product is involved

II. Factor rating

Factor rating is a technique that can be applied to a wide range of decisions. A typical location decision involves both qualitative and quantitative inputs. Factor rating is a general approach to evaluating locations that includes these quantitative and qualitative inputs.

STEPS: 1) determine which factors are relevant

2) assign a weight to each factor that indicates its relative importance compared with all others
→ Weights typically sum to 1.00

3) decide on a common scale for all factors, and set a minimum acceptable score if necessary

4) score each location alternative

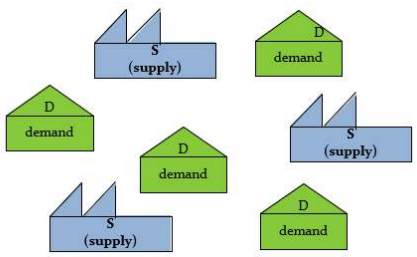
5) multiply the factor weight by the score of each factor, and sum the results for each alternative

6) choose the alternative with the highest score, unless it fails to meet the minimum acceptable score

III. Transportation model

Transportation problems involve finding the lowest-cost plan for distributing a stock of goods or supplies from multiple points of origin to multiple destinations that demand the goods.

It can also be used if a number of new facilities are to be added or if an entire new system is being developed.



Transportation problems can be solved **manually** in a straightforward manner.

→ Except for very small problems, solving the problem manually can be very time consuming.

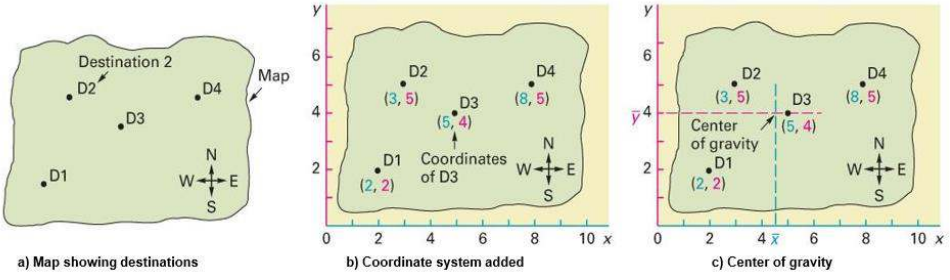
For medium to large problems, **computer solution techniques** are more practical. These computer solution techniques can be exact or heuristic. A variety of software packages are available for solving the transportation model:

- Some require formulating the problem as a general LP model (linear programming slide 32).
- Others allow data entry in a more simple, tabular format.

IV. Centre of gravity method

It's a method to determine the location of a facility that will minimize shipping costs or travel time to various destinations. Plus, it's a method for locating a distribution centre that minimizes distribution costs.

It treats distribution costs as a **linear function** of the distance and the quantity shipped. The quantity that needs to be shipped to each destination is assumed to be fixed. However, quantities are allowed to change, as long as their relative amounts stay the same (e.g. seasonal variations). The method includes the use of a **map** that shows the location of destinations. The map must be accurate and draw, to scale. A coordinate system is overlaid on the map to determine relative locations. The location of the (0,0) point and its scale is unimportant.



If the quantities to be shipped to every location are **equal**, you can obtain the coordinates of the centre of gravity by finding the **average** of the *x*-coordinates and the **average** of the *y*-coordinates.

$$\bar{x} = \frac{\sum x_i}{n} \qquad \text{and} \qquad \bar{y} = \frac{\sum y_i}{n}$$

When the quantities to be shipped to every location are **unequal**, you can obtain the coordinates of the centre of gravity by finding **the weighted average** of the *x*-coordinates and *y*-coordinates.

$$\bar{x} = \frac{\sum x_i Q_i}{\sum Q_i} \qquad \text{and} \qquad \bar{y} = \frac{\sum y_i Q_i}{\sum Q_i}$$

Inventory management

Inventory	A stock or store of goods

Many items that the firms have in inventory relate to the kind of business they engage in.

- **Independent-demand items**: items that are ready to be sold or used
- **Dependent-demand items**: items that are components of the finished items, rather than being the finished items themselves.

Inventories are a vital part of business, (1) they are necessary for operations but (2) they also contribute to customer satisfaction.

→ A typical firm has about 30% of its current assets and perhaps as much as 90% of its working capital invested in inventory!

There are ***DIFFERENT TYPES OF INVENTORY***:

- Raw materials and purchased parts
- Partially completed goods, called *work-in-process (WIP)*
- Finished-goods inventory or merchandise
- Tools and supplies
- Maintenance and repair (MRO) inventory
- Goods-in-transit to warehouses, distributors, or consumers (**pipeline inventory**)

Functions of inventories

Inventories serve a number of functions, among the most important are:

1. **To meet anticipated customer demand**: they are held to satisfied expected demand, it's *cycle stock.*
2. **To smooth production requirements:** You produce steadily, at one point in time you will produce more than the demand, then you create an inventory. At other times you produce less than your demand but then you can use your inventory. (golfachtige curve)
3. **To decouple operations**: Inventory in between two processes as buffer stock. Because if there is a problem with process 1 then you don't have stock for process 2. So you put stock in between them, then process 2 can continue with its operation.
4. **To protect against stockouts**: delayed deliveries and unexpected increases in demand increase the risk of shortages. Delays can occur because of weather conditions, supplier stock outs, etc. This risk can be reduced by holding *safety stock.*
5. **To take advantage of order cycles**: By ordering higher quantities you have an economy of scale. And it is economical to produce in large rather than small quantities.
6. **To hedge against price increases**: If there is an expectation that the price will increase, then you buy in advance. And you'll create an inventory.
7. **To permit operations**: production operations take a certain amount of time, so there will be WIP inventory. In addition, intermediate stocking of goods, leads to pipeline inventories. Little's law can be useful in quantifying pipeline inventory.
8. **To take advantage of quantity discounts**: suppliers may give discounts on large orders.

Little's Law	The average amount of inventory in a system is equal to the product of the average demand rate and the average time a unit is in the system.

Objectives of inventory management

Inventory management has two main concerns:

1. Level of customer service
   → Having the right goods available in the right quantity in the right place at the right time
2. Costs of ordering and carrying inventories

The overall objective of inventory management is to achieve satisfactory levels of customer service while keeping inventory costs within reasonable boundaries. The two basic issues for inventory management are: when to order & how much to order.

Managers have a number of **performance measures** they can use to judge the effectiveness of inventory management.

- Cost and customer satisfaction
  - Measured by the number and quantity of backorders and/or customer complaints
- **Inventory turnover**
  - The ratio of annual costs of goods sold to average inventory investment. This indicates how many times a year the inventory is sold.

Effective inventory management

Management has two basic functions concerning inventory. One is to establish a system to keep track of items in inventory, and the other is to make decisions about how much and when to order.

To be effective, the management must have the following:

1. A system to **keep track of inventory**
2. A reliable **forecast of demand**
3. Knowledge of **lead time** and **lead time variability**
4. Reasonable estimates of inventory
   - **holding costs:** how much does it cost me to keep one item in stock?
   - **ordering costs:** how much does it cost me to obtain one order?
   - **shortage costs:** if I go out of stock, how much does that cost me?
5. A **classification system** for inventory items

Let's take a closer look at each of these requirements!

Inventory counting systems

Periodic	Physical count of items in inventory made at periodic intervals.
perpetual	System that keeps track of removals from inventory continuously, thus monitoring current levels of each item.

- **Periodic systems**

Many small retailers use this approach. Every period the manager checks the shelves and counts the inventory (every day, every week, etc.). Then the manager estimates how much will be demanded next period. And based on that, he places an order.

- **Perpetual inventory system / continuous review system**

When the amount on hand reaches a predetermined minimum, a fixed quantity Q is ordered. There are different ways to do this.

> → **Two-bin system**: you have one product and you put two containers of inventory of that product in stock. If your employee sees that he takes the last piece out of the first bin a new order must be placed. Your operation system must give you a warning. For now however, the operator can continue the process because there is still the second bin. Your operator is still there.

Continuous review is more intense than periodic review because this you only have to do once in a certain time.

- **Universal product code (UPC)**

Supermarkets etc. were major users of periodic systems but today most of them switched to a computerised check out system using a laser scanner to scan bar codes or **universal product code.**

Universal product code	Bar code printed on a label that has information about the item to which it is attached.

- **Radio frequency identification tags (RFID)**

This is used to record items at the time of sale. It uses radio waves to identify objects, such as goods, in supply chains.

Inventory costs

Four basic costs are associated with inventories:

- **Purchase cost**: the amount paid to a supplier to buy the inventory
- **Holding or carrying costs**: cost to carry an item in inventory for a length of time, usually a year
- **Ordering costs**: costs of ordering and receive inventory
- **Setup costs**: the costs involved in preparing equipment for a job, 'machine set-up costs' (when a firm produces its own inventory)
- **Shortage costs**: costs resulting when demand exceeds the supply of inventory, often unrealized profit per unit

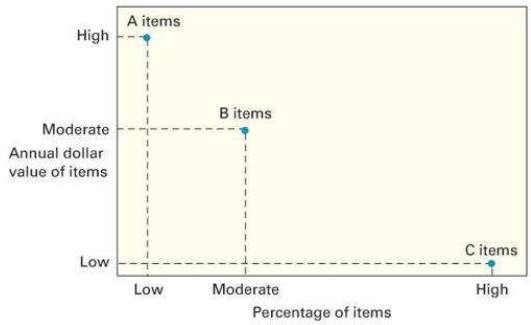
ABC classification system

A-B-C approach	Classifying inventory according to some measure of importance, and allocating control efforts accordingly.

→ The measure of importance is usually **annual dollar value**.

Three classes of items are used:

- **A = very important**
  Account for about 10 to 20% of the number of items in inventory but about 60 to 70% of the annual dollar value
- **B = moderate important**
- **C = least important**
  Account for about 50 to 60% of the number of items in inventory but only about 10 to 15% of the annual dollar value



The higher the demand rate or the higher the value of the good, the more accurate you want to keep track of the inventory. You can save a lot of money if you keep track of your inventory on an accurate way, but doing this also costs a lot of money. So it's best if you do it accurately for very important products with a high value, and for products that aren't as important (because their value isn't that high) you don't have to use such expensive ways. You can use a periodical approach or something. (Even though the volume of these products is quite high). This doesn't mean that C items are unimportant!

Another application of the A-B-C concept is as a guide to **cycle counting**.

Cycle counting	A physical count of items in inventory.

The purpose of cycle counting is to reduce discrepancies between the amounts indicated by inventory records and the actual quantities of inventory at hand. Accuracy is important because inaccurate records can lead to disruptions in operations, poor customer service and unnecessarily high inventory carrying costs.

The key questions concerning cycle counting for management are:

- **How much accuracy is needed?**
  - A items: ± 0.2 percent
  - B items: ± 1 percent
  - C items: ± 5 percent
- **When should cycle counting be performed?**
- **Who should do it?**

Inventory ordering policies

Inventory ordering policies address two basic issues of inventory management:

- When should an order be placed?
- How much should be ordered?

Cycle stock	The amount of inventory needed to meet expected demand.
Safety stock	Extra inventory carried to reduce the probability of a stock out due to demand and/or lead time variability

Deterministic and constant demand

The question of how much to order can be determined by using an **economic order quantity (EOQ) model**. These models identify the optimal order quantity by minimizing the sum of certain annual costs that vary with order size and order frequency.

Three order size models are described:

1. Basic economic order quantity model
2. The economic production quantity model
3. the quantity discount model

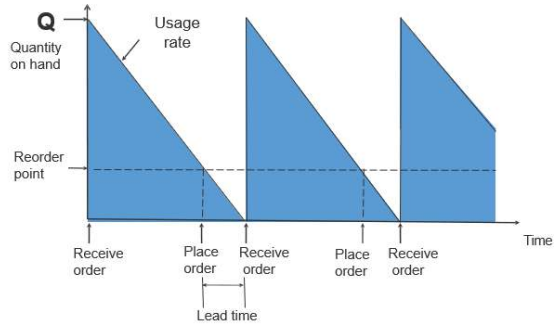
1. Basic economic order quantity model (EOQ)

It is used to identify a fixed order size that will minimize the sum of the annual costs of holding inventory and ordering inventory. The basic model involves a number of assumptions:

1. Only one product is involved
2. Annual demand requirements are known
3. Demand is even throughout the year
4. Lead time does not vary
5. Each order is received in a single delivery
6. There are no quantity discounts

Inventory ordering and usage occur in **cycles**.

A cycle begins with receipt of an order of Q units, which are withdrawn at a constant rate over time. When the quantity on hand is just enough to satisfy demand during lead time, an order of Q units is submitted. Because it is assumed that both the usage rate and the lead time do not vary, so the order will be received at the precise instant that the inventory on hand falls to zero.



Reorder point: you have to order a little bit before your stock is completely depleted. When you reached the reorder point you need to place a new order. It is the moment or quantity at which you should say that it's time to place a new order.

→ this is **cycle stock**

The **optimal order quantity** is a balance between carrying costs and ordering costs, one type of costs will increase while the other decreases when the order size varies.

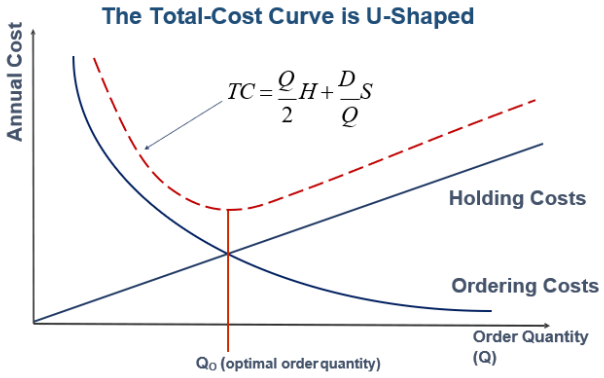
Total Cost = Annual Holding Cost + Annual Ordering Cost

$$= \frac{Q}{2} H + \frac{D}{Q} S$$

Where Q = Order quantity in units
H = Holding (carrying) cost per unit, usually per year
D = Demand, usually in units per year
S = Ordering cost per order

Annual Holding Cost: At Q/2 you have your **average inventory level**. This you multiply by H (the cost for holding something in inventory for one year).

Annual ordering cost: D/Q = the number of orders per year. You multiply this by the ordering cost per order S.



The total cost curve for different Q values. If you take lower Q values your cost will go up, but if you take higher Q values, your costs will go up as well. → if you have to decide to order a little bit more than the optimal ordering quantity or order a bit less, then it's better if you order a bit more because the curve on the left is steeper.

We need to find an optimal order quantity, so we can optimize the costs. This you do by taking the first derivative of this formula and equal it to zero. So, we have to set the derivative (slope) equal to zero and solve for Q. *The total cost curve reaches its minimum where the carrying and ordering costs are equal!*

$$Q_O = \sqrt{\frac{2DS}{H}} = \sqrt{\frac{2(\text{annual demand})(\text{order cost})}{\text{annual per unit holding cost}}}$$

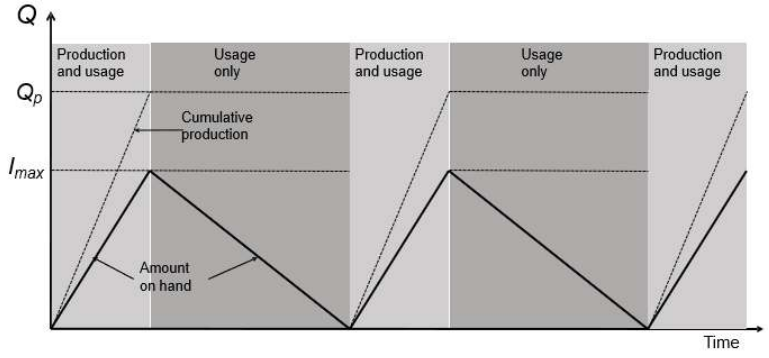
→ *This comes from finding the minimum of the curve (you have to know the background).*

2. *Economic production quantity model (EPQ)*

The batch mode is widely used in production. The reason for this is that in certain instances, the capacity to produce exceeds the part's usage or demand rate. So as long as production continues, inventory will continue to grow. In these instances it makes sense to periodically produce items in batch, instead of producing continuously.

The assumptions are largely the same as with the EOQ model, except that instead of orders received in a single delivery, units are received incrementally during production:

1. Only one item is involved
2. Annual demand requirements are known
3. Usage rate is constant
4. Usage occurs continually, but production occurs periodically
5. The production rate is constant
6. Lead time does not vary
7. There are no quantity discounts



During the production phase of the cycle inventory builds up at a rate equal to the difference between production and usage rates. If the daily production rate is 20 units and the daily usage rate is 5 units, inventory will build up at 15 units a day. As long as production occurs the inventory level will continue to build. When production stops, the inventory will begin to decrease. Hence, the inventory will be maximum at the point where production stops. When the amount of inventory on hand is exhausted, production is resumed, and the cycle repeats itself.

$$\mathbf{TC_{min} = carrying\ cost + setup\ cost}$$

$$\mathbf{= \left(\frac{I_{max}}{2}\right)H + \frac{D}{Q}S}$$

Where: I_{max} = maximum inventory = $\frac{Q_p}{p}(p - u)$ ➔ $I_{max} = Q_p - (\frac{Q_p}{p}).u$

P = production or delivery rate

U = usage rate, which is equal to D because your usage rate is actually equal to your demand

$\frac{Q_p}{p}$ = run time

3. ***Quantity discount model***

Quantity discounts are price reductions for larger orders offered to customers to induce them to buy in large quantities. When quantity discounts are available there are a number of questions that must be addressed to decide whether to take the advantage of discount or not.

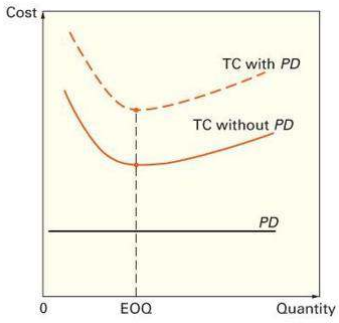
→ will additional storage space be available?
→ will obsolescence or deterioration be an issue?
→ can we afford to tie extra funds in inventory?

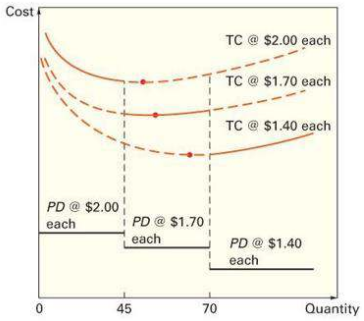
$$\mathbf{Total\ cost = carrying\ cost + ordering\ cost + purchasing\ cost}$$

$$\mathbf{= \frac{Q}{2}H + \frac{D}{Q}S + P.D}$$

Where P = unit price

If you order between e.g. 0 and 100 units, you get price P1. When you order between 100 and 200 you get price P2. When you order more than 200 you get price P3. → **quantity discount** with P1 > P2 > P3





→ Adding PD does not change your EOQ. So if you have a fixed price, the minimum is at exactly the same quantity, as you can see on the left graph.

→ The total-cost curve with quantity discounts is composed of a portion of the total-cost curve for each price. If you order less than 45 units, your price per piece is $2,00 etc. As you can see on the right graph.

Stochastic demand

EOQ models answer the question of how much to order, but not the question of **when to order**. The latter is the function of models that define the **reorder point (ROP)** in terms of a quantity.

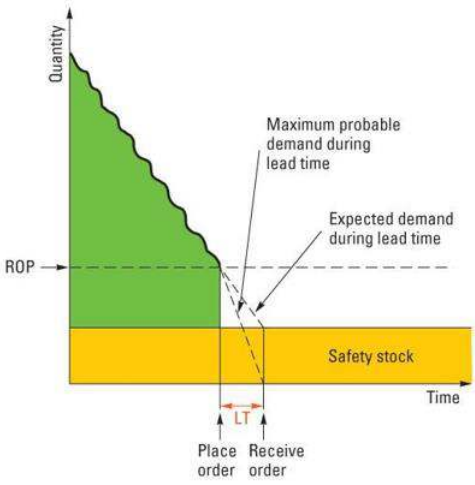
Reorder point (ROP)	When the quantity on hand of an item drops to this amount, the item is reordered

Determinants of the reorder point are:

- The rate of demand
- The lead time
- The extent of demand and/or lead time variability
- The degree of stock risk acceptable to management

ROP = *d* x LT

Where: *d* = demand rate (units per period, per day, per week)
LT = lead time (in the same time unit as *d*)



If there is variability in demand or lead time, it is possible that actual demand will exceed expected demand, so that the demand will be higher that the available supply. To reduce the likelihood of a **stockout**, you can carry **safety stock**.

Safety stock	Stock that is held in excess of expected demand due to variable demand and/or lead time.

ROP = expected demand during lead time + safety stock

⚠ NOTE: stockout protection is only needed during lead time!

But it costs money to hold safety stock, so a manager must carefully weigh the cost of safety stock against the reduction in stockout risk it provides. The customer service level increases, as the risk of stockout decreases!

Service level = 100% - stockout risk

Service level	Probability that demand will not exceed supply during lead time.

The **amount of safety stock** that is appropriate for a given situation depends upon:

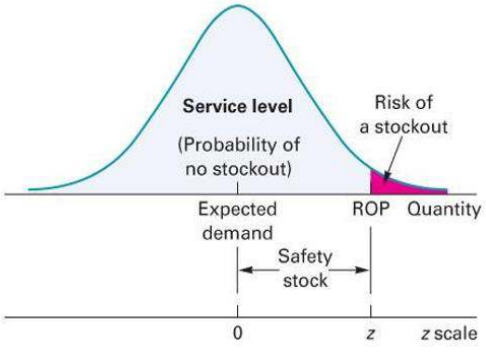
- The average demand rate and average lead time
- Demand and lead time variability
- The desired service level

For a given service level, the greater the variability in either demand or lead time, the greater the amount of safety stock that will be needed to achieve that service level. Selection of a service level may reflect stockout costs.

1) *If an estimate of expected demand during lead time and standard deviation are available*

ROP = Expected demand during lead time + $z\sigma_{dLT}$

Where: z = number of standard deviations
σ_{dLT} = the standard deviation of lead time demand



Assume that your demand is normally distributed, your average demand is 50 units/week but it can be more or less.

If you take the mean μ and you add one time the mean deviation σ → **μ + 1σ** then you know that you will have enough in stock

z = 1 → SL = 84%
z = 2 → SL = 97,7%
z = 3 → SL = 99,9%, here you cover almost all your demand

If you want a higher service level (SL), you have to take higher z values. You can get the percentage that is covered by a certain z values from tables on normal distributions. (but we don't have them, they are not in the book). This is true for ALL normal distributions!

If data on lead time demand is not available, the previous formula cannot be used.

2) *If only demand is variable*

→ Then is $\sigma_{dLT} = \sigma_d \sqrt{LT}$ and the reorder point is:

ROP = $\bar{d}$ x LT + $z\sigma_d \sqrt{LT}$

Where: $\bar{d}$ = average daily or weekly demand
σ_d = standard deviation of demand in days or weeks
LT = lead time in days or weeks

3) *If only lead time is variable*

→ Then is $\sigma_{dLT} = d\sigma_{LT}$ and the reorder point is:

$$\textbf{ROP} = d \times \overline{LT} + zd\sigma_{LT}$$

Where: $\overline{LT}$ = average lead time in days or weeks
σ_{LT} = standard deviation of lead time in days or weeks
d = daily or weekly demand

4) *If demand and lead time are variable/uncertain*

→ Then is $\sigma_{dLT} = \sqrt{\overline{LT}\,\sigma^2_d + \bar{d}^2\sigma^2_{LT}}$ and the reorder point is:

$$\textbf{ROP} = \bar{d} \times \overline{LT} + z\sqrt{\overline{LT}\,\sigma^2_d + \bar{d}^2\sigma^2_{LT}}$$

Where: $\overline{LT}$ = average lead time in days or weeks
σ_{LT} = standard deviation of lead time
σ_d = standard deviation of demand period
$\bar{d}$ = average demand per period
z = number of standard deviations

Fixed-order-interval model

Fixed-order-interval (FOI)	Orders are placed at fixed time intervals. The timing of the orders is set.

This is a quite different approach from an EOQ/ROP approach in which the order size generally remains fixed from cycle to cycle, while the length of the cycle varies.

Reasons for using the FOI model:

- Supplier's policy may encourage its use
- Grouping orders from the same supplier can produce savings in shipping costs
- Some circumstances do not lend themselves to continuously monitoring inventory position
  → (e.g. drugstores, small grocery stores)

Determining the amount to order:

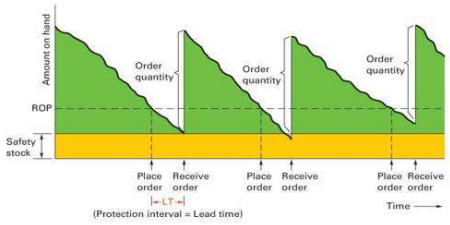
→ **Fixed-interval-model**

- Orders are triggered by a *time*
- Stockout protection for the lead time + the next order cycle
- A greater need for safety stock
- A higher-than-normal demand results in *larger order size*
- Requires only a periodic review of inventory levels

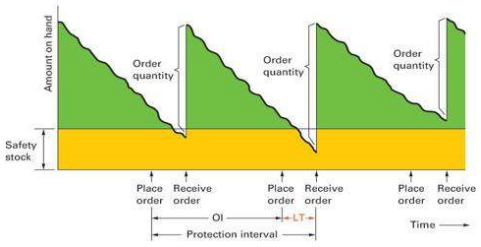
→ **Fixed-quantity-model**

- Orders are triggered by a *quantity (ROP)*
- Stockout protection is only needed during lead time, additional orders can always be placed
- A higer-than-normal demand creates a *shorter time between orders*
- Requires close monitoring of inventory levels

Fixed Quantity



Fixed Interval



Fixed-quantity-interval (lower): the order quantity changes, but you always order at the same time.
Fixed-order-interval (upper): the order quantity is always the same, but it is not always ordered at the same time.

$$\text{Amount to order} = \begin{matrix}\text{expected demand during}\\ \text{protection interval}\end{matrix} + \text{safety stock} - \begin{matrix}\text{amount on hand}\\ \text{at reorder time}\end{matrix}$$

$$Q = \bar{d}\,(OI + LT) + z\sigma_d\sqrt{OI + LT} - A$$

Where: OI = order interval (length of time between orders)
A = amount on hand at reorder time

Single-period model

Single-period model	Model for ordering perishables and other times with limited useful lives.

→ Perishables: fresh fruits, vegetables, seafood, cut flowers, …
→ Limited useful lives: newspapers, magazines, spare parts, …

Shortage cost: the unrealized profit per unit (i.e. profit/unit – cost per unit)

$$C_{shortage} = C_s = \text{Revenue per unit} - \text{cost per unit}$$

If a shortage or stockout relates to an item used in production or to a spare part for a machine, then shortage cost refers to the actual cost of lost production.

Excess cost: difference between purchase cost and salvage value of items left over at the end of a period.

$$C_{excess} = C_e = \text{original cost per unit} - \text{salvage value per unit}$$

If there is cost associated with disposing of excess items, the salvage will be negative and will therefore increase the excess cost per unit.

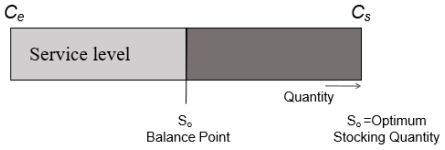
The goal of the single-period model is to identify the order quantity that will minimize the long-run excess and shortage cos. But there are two categories of problem:

- Demand can be characterized by a continuous distribution *(e.g. demand for gases, oil, liquids, …)*
- Demand can be characterized by a discrete distribution *(e.g. demand for cars, computers, …)*

The service level is the probability that demand will not exceed the stocking level, and computation of the service level is key to determining the **optimal stocking level S_o**.

$$\textbf{Service level} = \frac{C_s}{C_s + C_e}$$

If actual demand exceeds S_O, there is a shortage. Hence, C_s is on the right end of the distribution. If demand is less than S_O, there is an excess. So C_e is on the left end of the distribution. When $C_e = C_s$ the optimal stocking level is halfway between the endpoints of the distribution. If one point is greater than the other, S_O will be closer to the larger cost.



When demand is normally distributed: $\mathbf{S_O = mean + z \times \sigma}$

Supply chain management (SCM)

What is supply chain management?

Supply chain	The sequence of organizations – their facilities, functions, and activities – that are involved in producing and delivering a product or service.

FACILITIES

The sequence of the supply chains begins with basic suppliers and extends all the way to the final customer:
- warehouses
- factories
- processing centers
- distribution centers
- retail outlets
- offices

FUCTIONS AND ACTIVITIES

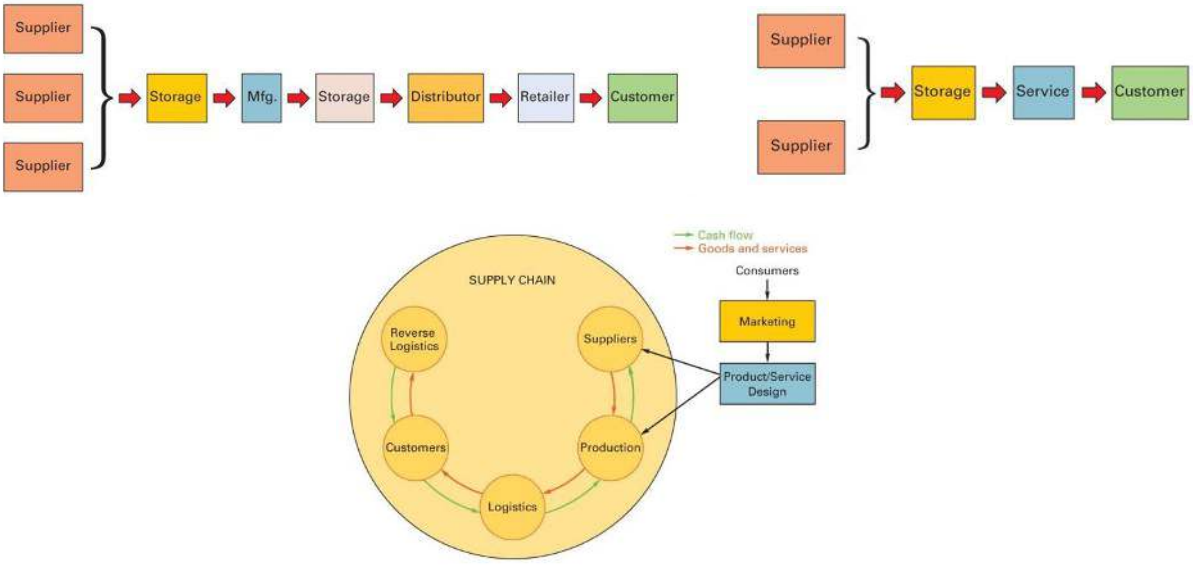
Supply chain functions and activities include:
- forecasting
- purchasing
- inventory management
- Information management
- Quality assurance
- Scheduling
- Production and delivery
- Customer service

Logistics	The part of the supply chain involved with the forward and reverse movement of goods, services, cash and information in a supply chain.

Logistics management includes management of inbound and outbound transportation, material handling, warehousing, inventory etc.

Every business organization is part of at least one supply chain, many are even part of multiple supply chains. Often the number and size of organizations in a supply chain are determined by whether the supply chain is **manufacturing** or **service oriented**.

a) manufacturing oriented **b) service oriented**



Supply chain management

Supply chain management (SCM)	The strategic coordination of the supply chain and business functions within a business organization, for the purpose of integrating supply and demand management.

Supply chain managers are people at various levels of the organization who are responsible for managing supply and demand both within and across business organizations. They are involved with coordinating and planning activities:

- sourcing and procurement of materials and services
- transformation activities
- logistics

The **goal** of SCM is to match supply to demand as effectively and efficiently as possible.
Key aspects are:

- Determining appropriate levels of outsourcing
- Managing procurement
- Managing suppliers
- Managing customer relationships
- Being able to quickly identify problems and respond to them

An important aspect of SCM is ***flow management*****!**
The three types of flow that need to be managed are:

- **Product and service flow**
  Involves movement of goods and services from suppliers to customers as well as handling customer service needs and product returns

- **Information flow**
  Involves sharing forecasts and sales data, transmitting orders, tracking shipments, and updating order status

- **Financial flow**
  Involves credit terms, payments, and consignment and title ownership arrangements

Trends in supply chain management

Many business emphasize the following trends, affecting supply chain and management:

- **Measuring supply chain ROI**
  This enables managers to incorporate economics into outsourcing and other decisions, giving them a rational basis for managing their supply chain.

- **"Greening" the supply chain**
  This generates interest for a variety of reasons, including corporate responsibility, regulations and public pressure. This may involve redesigning products and services, reducing packages, near-sourcing to reduce pollution from transportation, choosing green suppliers etc.

- **Re-evaluating outsourcing**
  Companies are taking a second look on outsourcing. Reconsidering advantages and disadvantages of outsourcing sometimes leads to **back-shoring**.

    - ADVANTAGES: Lower prices may result from lower labour costs, the organization can focus on its core strengths and outsource other things, some fixed costs can be made variable, it can free up capital to address other needs, some risks can be shifted to the supplier and you can take advantage of the supplier's expertise. Plus it makes it easier to expand outside of the home country because people might think "*Oh it is produced in my country so it will be good*".

    - DISADVANTAGES: Inflexibility due to longer lead times, increased transportation costs, language and cultural differences, loss of jobs, control and business knowledge, lower productivity, there is knowledge transfer and intellectual property concerns, finally increased efforts are required to manage the supply chain.

- **Integrating IT**
  This produces real-time data that can enhance strategic planning and help businesses to control costs, measure quality and productivity, respond quickly to problems and improve operations. This is why **ERP** systems are so important for SCM. *E.g. SAP, Microsoft Dynamics, …*

    - **ERP**: provides a system to capture and make data available in real time to decisions makers and users throughout an organization. It also provides the ability to coordinate, monitor and manage a supply chain. ERP systems are compared with a collection of integrated modules. They have wide visibility in areas such as:

        - Supplier Relationship Management: e.g., lead times, quality
        - Performance Management: e.g., profits, productivity
        - Sales and Order Fulfillment: e.g., returns, delivery dates
        - Customer Relationship Management: e.g. details on contracts, payment terms, etc.

For an overview of ERP software modules see slide 16!

- **Adopting lean principles**
  Applying lean principles to supply chains can overcome this weakness by eliminating non-value added processes. Lean is a Japanese manufacturing/managing **philosophy**.

Lean operations	A flexible system of operation that uses considerably less resources than a traditional system.
Lean supply chain	Focused on eliminating non-value-added activities to create an efficient, low-cost supply chain.

You need to try to avoid non value adding activities in your company. Also on the level of supply chains, people try to diminish waste, get rid of non-value adding activities, work more effective → apply lean

Lean tends to achieve: lower costs, greater productivity, shorter time cycles and higher quality!

Lean systems are sometimes referred to as **just-in-time (JIT)** systems owing to their highly coordinated activities and delivery of goods that occur just as they are needed. Just-in-time is sometimes used as an alternative name for lean because producing things just in time so you won't have to keep them in inventory too long, that is lean.

- **Managing risks**
  For some business the supply chain is a major source of risk, so it is essential to adopt procedures for managing risks (see later).

- **Being agile**
  A supply chain must be flexible enough to respond fairly quickly to unpredictable changes or circumstances.

Supply chain risks and risk management

Supply Chain Risks can be:

- Supply chain disruption: due to natural disasters or supplier problems
- Quality Issues: this is another form of disruption that may disrupt supplies and lead to product recalls, liability claims, and negative publicity
- Loss of control of sensitive information: If suppliers divulge sensitive information to competitors, it can weaken a firm's competitive position

Resiliency	The ability of a business to recover from an event that negatively impacts the supply chain.

→ Business can reduce, but not eliminate, the need for resiliency by managing their risks!

RISK MANAGEMENT

Risk management involves identifying risks, assessing their likelihood of occurring and their potential impact and then developing strategies for addressing those risks. Potential strategies are:

- Risk avoidance: e.g. not dealing with suppliers in a certain area
- Risk reduction: e.g. replacing unreliable suppliers
- Risk sharing: e.g. contractual arrangements with supply chain partners that spread the risk

Key elements to managing risks include:

- **Know your suppliers**
  Mapping the supply chain can be helpful in grasping the scope of the supply chain, identifying suppliers and seeing if there are any supplier concentrations. This might lead to the desirability of simplifying the supply chain.

- **Provide supply chain visibility**
  = A major trading partner can connect to its supply chain to access data in real time on inventory levels, shipment status and similar key information.

- **Develop event-response capability**
  = The ability to detect and respond to unplanned events. Such as delayed shipment or a warehouse running low on a certain item.

Global supply chains

As businesses increasingly make use of outsourcing and pursue opportunities beyond their domestic markets, their supply chains are becoming increasingly global.

→ product design uses inputs from around the world, and products are sold globally.

Some manufacturing and service activities are outsourced to countries where labour and/or materials costs are lower.

Bu global supply chains also have additional **complexities** such as:
Language and cultural differences, currency fluctuations, political instability, increasing transportation costs and lead times, increased need for trust amongst supply chain partners, …

Ethics and the supply chain

Every company should develop an **ethical supply chain code** to guide behaviour. A code should cover behaviours that involve customers, suppliers, suppliers' behaviours, contract negotiation, recruiting and the environmental issues.

Key steps companies can take to reduce the risk of damages due to unethical supplier behaviour are to choose those that have a reputation for good ethical behaviour; incorporate compliance with labour standards in supplier contracts; and address quickly any ethical problems that occur.

Examples:
- Bribing government or company officials to secure permits or favorable status
- "Exporting smokestacks" to developing countries
- Claiming a "green" supply chain when the level of "green" is only minimal
- Ignoring health, safety, and environmental standards
- Violating basic worker rights
- Mislabeling the country of origin
- Selling products abroad that are banned at home

Small businesses

Small business do not always give adequate attention to their supply chains. However, there are many benefits to be had for small businesses by actively managing their supply chains. Their size can actually be a competitive advantage, because small businesses are often more agile than larger companies, enabling them to make decisions and changes more quickly when the need arises.

Three small business SCM concerns are:

- **Inventory management**
  Small businesses may carry extra inventory as a way to avoid shortages due to supply chain interruptions. However, that can tie up capital and take up space. An alternative is to have backup suppliers for critical items.

- **Reducing risks**
  The key to reducing risks is managing suppliers. Important steps are:
  - Use only reliable suppliers
  - Determine which suppliers are critical and get to know them and any challenges they have
  - Measure supplier performance
  - Recognize warning signs of supplier issues
  - Have plans in place to manage supply chain problems

- **International trade**
  Exporting can offer opportunities for small business producers to greatly expand their businesses, although they typically lack the knowledge to do so.

Importing can have benefits for small companies. Some tips are:

- Work with someone who has expertise to help oversee foreign suppliers
- Set expectations for demand and timing
- Do not rely on a single supplier
- Build goodwill to help in negotiations and resolving any problem that arise
- Consider using domestic suppliers if the risks of working with foreign suppliers are prohibitive

Management responsibilities

- **Legal responsibilities**
  Include being knowledgeable about laws and regulations of the countries where supply chain exists, obeying laws and operating to conform to regulations.

- **Economic responsibilities**
  Supplying products and services to meet demand as efficiently as possible.

- **Ethical responsibilities**
  Include conducting business in ways that are consistent with the moral standards of society.

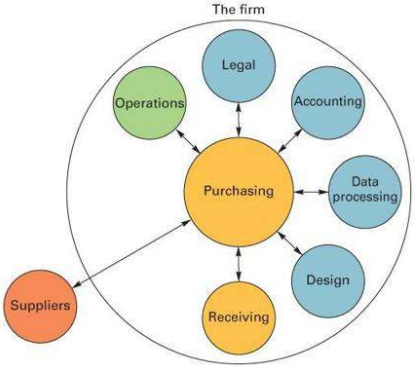
Procurement

Procurement	The act of obtaining or buying goods and services

The purchasing department of an organization is responsible for obtaining the materials, parts, suppliers and services needed to produce a product or provide a service. But the importance of purchasing is more than just the cost of goods purchased; important factors include the quality of goods and the timing of deliveries.

The **goal** of procurement is to develop and implement purchasing plans for products and services that support operations strategies.

Purchasing interfaces



Purchasing has interfaces with a number of functional areas, as well as with outside suppliers. It is the connecting link between the organizations and its suppliers.

Operations: the main source of requests for purchased materials, and close cooperation between these units and the purchasing department is vital if quality, quantity and delivery goals are to be met.

Legal: helps interpret legislations on pricing, product liability and contracts with suppliers.

Accounting: responsible for handling payments

Data processing: keeps inventory records, checks invoices and monitors vendor performance

Design: prepare materials specifications. Design and purchasing may work closely together to determine whether changes in specifications, design, or materials can reduce the cost of the purchased items.

Receiving: checks incoming shipments of purchased items to determine whether quality, quantity and timing objectives have been met, and it moves the goods to temporary storage.

Suppliers: learn what materials will be purchased and what kinds of specifications will be required in terms of quantity, quality and deliveries.

The purchasing cycle

Purchasing cycle	A series of steps that begins with a request for purchase and ends with a notification of shipment received in the satisfactory condition.

1. **Purchasing receives the requisition**
   This includes a description of the desired items, the quantity and quality necessary, the desired delivery dates and who is requesting the purchasing.

2. **Purchasing selects a supplier**
   The supplier who has the capability of supplying the desired goods must be selected. If no suppliers are currently listed, purchasing has to seek new ones.

3. **Purchasing places the order with a vendor**
   For a large, one-time specific expenditure vendors will usually be asked to bid on the job. The operating an design personnel can be asked to help with negotiations. For a large-volume, continuous-usage items may be covered with blanket purchase orders. For moderate-volume items can also have blanket purchase orders, or they can be handled individually. And small purchases are handled directly between the operating unit requesting and the supplier.

4. **Monitoring orders**
   Routine follow-up on orders to project potential delays and relay that information to the operating units. The purchasing department must also communicate changes in quantities and delivery needs of the operating units to suppliers to allow them to change their plans.

5. **Receiving orders**
   Check incoming shipment on quality and quantity. Then notify purchasing, accounting and the operating units that the requested goods are received.

Supplier management

Choosing suppliers

A company considers price, quality, the supplier's reputation, past experience with the supplier and service after the sale. The main factors that a company has to take into account are:

Quality & quantity assurance, flexibility, location, price, product or service changes, reputation & financial stability, lead times and on-time delivery, other accounts.

Because different factors are important for different situations, purchasing must decide, with the help of operations, the importance of each factor and then rate the potential vendors according to how well they can be expected to perform against this list. → **vendor analysis**

Vendor analysis	Evaluating the sources of supply in terms of price, quality, reputation and service.

Supplier audits

Supplier audits are a means of keeping current on suppliers' production and service capabilities, quality and delivery problems and resolutions, and suppliers' performance on other criteria. If an audit reveals problem areas, a buyer can attempt to find a solution before more serious problems develop.

Supplier certification

This is a detailed examination of the policies and capabilities of a supplier. The certification process verifies that a supplier meets or exceeds the requirements of a buyer.

ADVANTAGE: the buyer can eliminate much or all of the inspection and testing of delivered goods. Plus there is much less risk than with noncertified suppliers.

Supplier relationship management

The type of relationship is often related to the length of the contract between buyers and sellers!

- **Short-term contracts**: involve competitive bidding. Companies post specifications and potential suppliers bid on the contracts. The relationship is minimal.
- **Medium-term contracts:** often involve ongoing relationships
- **Long-term contracts**: often evolve in partnerships, with buyers and suppliers cooperating on various issues than tend to benefit both parties.

Some businesses use **supplier forums** to educate potential suppliers about the organization's policies and requirements and the enhance opportunities for receiving contracts. Others use the forums to share information, strengthen cooperation and encourage joint thinking.
Some organizations use a **suppliers code of conduct** that requires suppliers to maintain safe working conditions, treat workers with respect and dignity, and have production processes that do not harm workers, customers and the environment.

Aspect	Adversary	Partner
Number of suppliers	Many; play one off against the others	One or a few
Length of relationship	May be brief	Long-term
Low price	Major consideration	Moderately important
Reliability	May not be high	High
Openness	Low	High
Quality	May be unreliable; buyer inspects	At the source; vendor certified
Volume of business	May be low due to many suppliers	High
Flexibility	Relatively low	Relatively high
Location	Widely dispersed	Nearness is important for short lead times and quick service

Supplier partnerships

Among the benefits of supplier partnerships are: higher quality, increased delivery speed and reliability, lower inventories, lower costs, higher profits and in general, improved operations.
BUT many of the benefits go to buyers, which might make suppliers more hesitant to enter into such a relationship. Suppliers may have to face increased investments in equipment etc.

→ **STRATEGIC PARTNERING**

Strategic partnering	Two or more business organizations that have complementary products or services join so that they each may realize a strategic benefit.

Example: *a supplier can agree to hold inventory for the buyer. In return the buyer agrees to a long-term commitment. In this way the buyer can save costs for inventory and the supplier can save costs for continuously searching new customers, negotiating prices and services, and so on.*

Collaborative planning, forecasting and replenishment (CPFR)	A contractual agreement used to achieve supply chain integration by cooperative management of inventory in the supply chain by major supply chain partners.

CPFR involves information sharing, forecasting and joint decision making. If done well, it can lead to cost savings on inventory, logistics and merchandising for the partners.

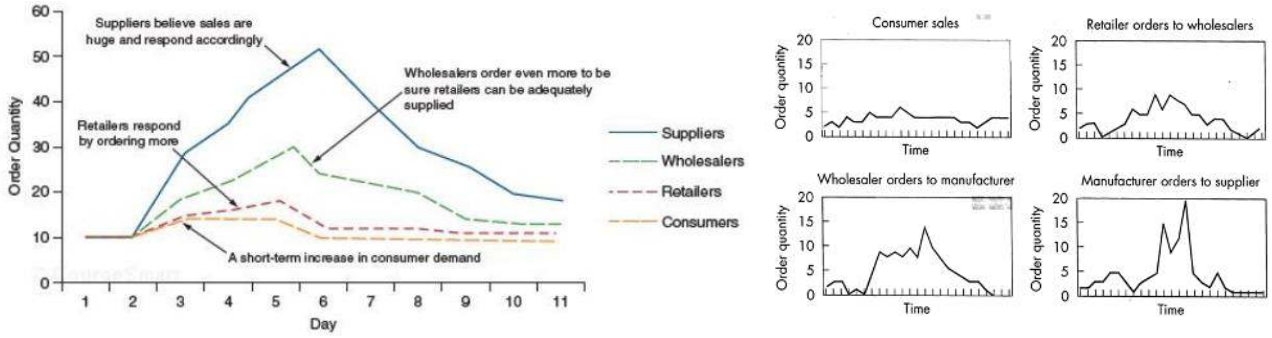
Inventory management and bullwhip effect

Certain aspects of inventory management are particularly important for supply chain management. They relate to the location of inventories in the supply chain, the speed at which inventory moves through the supply chain, and dealing with the effect of demand variability on inventories.

Inventory velocity	The speed at which goods move through a supply chain
Bullwhip effect	Inventory oscillations become progressively larger looking backward though the supply chain.

→ Without careful management, demand variations can easily cause inventory fluctuations to get out of control. Variations in demand at the customer end of a supply chain tend to ripple backwards through the chain. Periodic ordering and reaction to shortages can magnify variations, causing inventories to oscillate in increasingly larger swings.

Consequently shortages and surpluses occur throughout the chain, resulting in higher costs and lower customer satisfaction, unless preventive action is taken.



→ This effect was first noticed by P&G executives examining the order patterns for Pampers disposable diapers. They noticed that order variation increased dramatically as one moved from retailers to distributors to the factory. (See pictures)

PROBLEM: the bullwhip effect increases the difficulty of planning at the factory level.

Avoiding the bullwhip effect

You can overcome the bullwhip effect by **strategic buffering of inventory**, information sharing, and inventory replenishment based on needs. You can avoid that this happens by sharing more information, having good ERP systems.

Information transfer in supply chain can be accomplished by using **VMI**

Vendor-managed inventory (VMI)	Vendors monitor goods, by tracking goods shipped to distributors and retail outlets. And replenish retail inventories when supplies are low.

Information Transfer in Supply Chains: VMI

- **Just-in-time distribution (JITD)**: obtain sales data directly from distributors and decide on delivery sizes based on that information (as opposed to allowing distributors to independently decide on order sizes)
- **Enabling technologies**:
  - **EDI: Electronic Data Interchange:** Transmission of documents electronically in a predetermined format from company to company. (Not web based.) The formats are complex and expensive. It appears to be on the decline as web-based systems grow.
  - **Web-based transaction systems**

Order fulfilment

Fulfilment	The processes involved in responding to customer orders.

Fulfilment time is often a function of the degree of customization required. There are some common approaches:

- **Engineer-to-Order (ETO)**
  Products are designed and build according to customer specifications. This is frequently used for large-scale construction projects (homebuilding, home remodelling). The fulfilment time can be lengthy because of the nature of the project, as well as the presence of other jobs ahead of the new one.

- **Make-to-Order (MTO)**
  A standard product design is used, but production of the final product is linked to the final customer's specifications. Fulfilment time is generally less than with ETO fulfilment, but still fairly long.

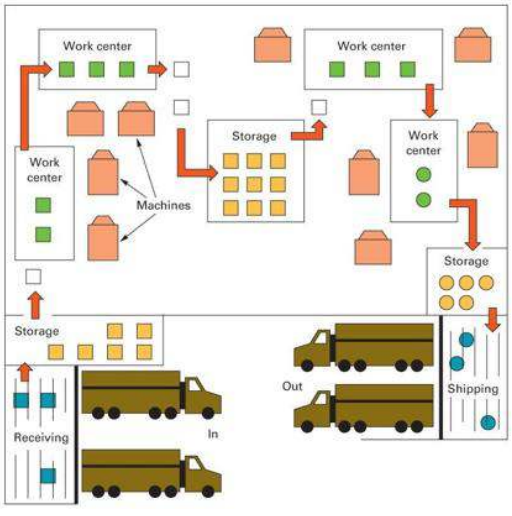
- **Assemble-to-Order (ATO)**
  Products are assembled to customer specifications from a stock of standard and modular components. Fulfilment times are fairly short, often a week or less.

- **Make-to-Stock (MTS)**
  Production is based on a forecast, and products are sold to the customer from finished good stocks. The order fulfilment time is immediate.

Logistics

Logistics	The movement of materials, services, cash and information in a supply chain. Logistics include movement within a facility, overseeing incoming and outgoing shipments of goods and materials, and information flow throughout the supply chain.

Movement within a facility



1. from incoming vehicles to receiving
2. from receiving to storage
3. from storage to the point of use
4. from one work centre to the next or temporary storage
5. from the last operation to final storage
6. from storage to packaging/shipping
7. from shipping to outgoing vehicles

Incoming and outgoing shipments

Traffic management	Overseeing the shipment of incoming and outgoing goods.

This function handles schedules and decisions on shipping method and times, taking into account:

- Costs of shipping alternatives
- Government regulations
- Needs of the organization relative to timing and quality
- Shipping delays or disruptions (external factors)

Tracking goods: RFID

Radio frequency identification (RFID)	A technology that uses radio waves to identify objects, such as goods in supply chains. This is done through the use of an RFID tag that is attached to an object.

These tags are similar to bar codes, but they have the advantage of conveying much more information, and they do not require a line-of-sight for reading that bar codes require. And unlike bar codes, which must be scanned individually and usually manually, multiple RFID tags can be read simultaneously and automatically. Plus an RFID tag provides more precise information than a car code.

This technology has the ability to:

- Increase supply chain visibility
- Improve inventory management
- Improve quality control
- Enhance relationships with suppliers and customers

RFID eliminates the need for manual counting and bar-code scanning of goods at receiving docks, in warehouses and on retail shelves. This eliminates errors and greatly speeds up the process.

3-PL

Third-party logistics (3-PL)	The outsourcing of logistics management

Some companies use third-party providers for shipping, others include warehousing and distribution, and still others rely on third-party companies to manage most or all of their supply chains.

Potential benefits include taking advantage of:

- The specialists' knowledge
- Their well-developed information system
- Their ability to obtain more favourable shipping rates
- Enabling the company to focus more on its core business

Aggregate planning and master scheduling

Manufacturing planning and control (MPC)

Essential tasks:

- Manage efficiently the flow of material
- Manage the utilization of people and equipment
- Respond to customer requirements
- Acquisition of information from customers on product needs
- Providing customers with information on delivery dates and product status
- MPC system does not make decisions nor manage operations, but it provides the information upon which managers make effective decisions

Organizations make capacity decisions on three levels:

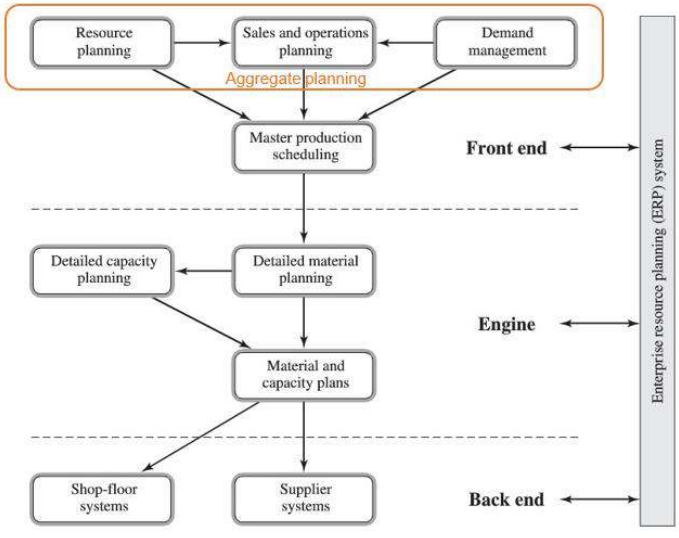
- **Long-term decisions (strategic level)**
  Relate to product and service selection, facility size and location, equipment decisions and layout of facilities. These decisions establish the capacity constraints within which intermediate planning must function.

- **Intermediate decisions (tactical level)**
  Relate to the general levels of employment, output and inventories. Which in turn establish boundaries within which short-range capacity decisions must be made.

- **Short-term decisions (operational level)**
  Deciding the best way to achieve desired results within the constraints resulting from long-term and intermediate-term decisions. Like scheduling jobs, workers and equipment.

This chapter is about INTERMEDIATE CAPACITY DECISIONS!

A key objective in business planning is to coordinate the intermediate plans of various organization functions. All of these functional areas must work together to formulate the aggregate plan. Aggregate planning decisions are strategic decisions that define the framework within which the operating decisions will be made.



Enterprise Resource Planning (ERP)

The MPC system is imbedded in an Enterprise Resource Planning (ERP) system:

ERP system	A comprehensive software approach to support decisions concurrent with **planning and controlling the business.**

→ ERP creates an integration of application programs in finance, manufacturing, logistics, sales and marketing, human resources, and other functions

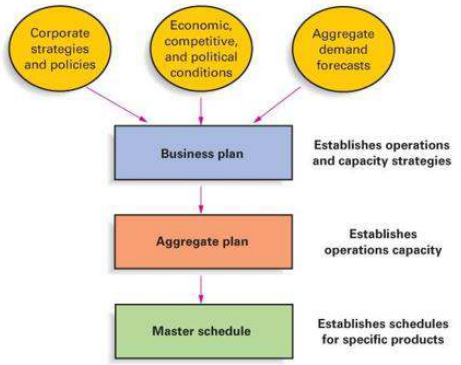
Aggregate planning

Aggregate planning	Intermediate-range capacity planning, usually covering a time horizon 2 to 12 months. Although in some companies it may extend to 18 months.

Aggregate planning is particularly useful for companies that experience **seasonal** or **other fluctuations in demand** or **capacity**.

GOAL: Achieve a production plan that will effectively utilize the organization's resources to satisfy expected demand. You can do aggregate planning for one type of product family, so you will know specifically how much you have to produce of that product family.

(If you do aggregation your errors will be smaller. Because you do it on an aggregate level and not on a single product basis.)



The aggregate plan will guide to a more detailed planning that eventually leads to a **master schedule**.

But planners essentially want a big-picture approach. So they focus on a group of similar products or services, or sometimes entire product lines.

→ they focus on overall demand and capacity

Why do organizations need to do aggregate planning?

The answer consists of two elements:

- **Planning**: it takes time to implement plans
- **Strategic**: aggregation is important because it's not possible to predict with any degree of accuracy the timing and volume of demand for individual items.

Generally speaking, aggregate planning is connected to the **budgeting process**. Aggregate planning is important because it can help **synchronize flow** throughout the supply chain; it affects costs, equipment utilization; employment levels; and customer satisfaction

- The plan must be in units of measurement that can be understood by the firm's non-operations personnel
  - Aggregate units of output per month
  - Dollar value of total monthly output
  - Total output by factory
  - Measures that relate to capacity such as labour hours

Dealing with variations

Most organizations use **rolling 3, 6, 9 and 12 month forecasts**

Rolling 3, 6, 9 and 12 month forecasts	Forecasts that are updated periodically, rather than relying on a once-a-year forecast.

This allows planners to take into account any changes in either expected demand or expected supply and to develop revised plans. In some business variations are more the norm than the exceptions. There are some strategies to counter these variations:

- **Maintain a certain amount of excess capacity to handle increases in demand**
- **Maintain a degree of flexibility in dealing with changes**
  This might involve hiring temporary workers or working overtime. (mostly for seasonal demand)
  → You hire more people
  → You can keep the same amount of people but let them work overtime
  → You can subcontract
- **Wait as long as possible before committing to a certain level of supply capacity**
  Scheduling products with known demand first, this shortens the time horizon and maybe enables the remaining products to become less uncertain.

An overview of aggregate planning

Forecast of aggregate demand for the intermediate range ⇨ Develop a general plan to meet demand requirements ⇨ Update the aggregate plan periodically

DEMAND AND SUPPLY. Aggregate planners are concerned with:

- **Demand quantity**: if expected demand exceeds available capacity, then try to achieve a balance by altering capacity, demand or both.
- **Timing of demand**: even if demand and capacity are largely equal, planners still often have to deal with uneven demand within the planning period.

The task of aggregate planners is to achieve rough equality of demand and capacity over the entire planning horizon.

AGGREGATE PLANNING INPUTS.

- **Resources**
  - Workforce/production rates
  - Facilities and equipment
- **Forecast of expected demand**
- **Policies regaring:**
  - Workforce changes
  - Subcontracting
  - Overtime
  - Inventory levels/changes
  - Back orders
- **Costs**
  - Inventory carrying
  - Back orders
  - Hiring/firing
  - Overtime
  - Inventory changes
  - subcontracting

AGGREGATE PLANNING OUTPUTS.

- **Total cost of a plan**
- **Projected levels of**
  - Inventory
  - Output
  - Employment
  - Subcontracting
  - Backordering

Aggregate planning strategies

Balance the advantages of producing to meet demand, closely against the disruptions caused by changing the levels of production and/or the workforce levels.

- **Proactive** or **demand strategies**
  Alter demand so that it matches capacity.
- **Reactive** or **capacity strategies**
  Alter capacity to match demand.
- **Mixed strategies**
  I will smooth my demand a bit but I will also alter my capacity to match my demand more.

Demand options

- **PRICING**: pricing is used to shift demand from peak periods to off-peak periods. To the extent that pricing is effective, demand will be shifted so that it corresponds more closely to capacity.
  An important factor to consider is **price elasticity**. The more the elasticity, the more effective pricing will be in influencing demand patterns.
- **PROMOTION**: advertisement and other forms of promotion can be effective to shift demand so that it conforms more closely to capacity.

- **BACK ORDERS**: orders are taken in one period and deliveries are promised in a later period. The success of this approach depends on how long your customers are willing to wait.

- **NEW DEMAND**: create new demand to make use of the excess capacity during slack times.

Supply options

- **HIRE AND LAY OFF WORKERS**: hiring more workers can create higher capacity

- **OVERTIME/SLACK TIME**: it can be implemented quickly and allows the firm to maintain a steady base of employees. The use of overtime can be attractive in dealing with seasonal demand peaks by reducing the need to hire and train more workers who will eventually be laid off during the off-season. Slack time on the other hand, can be used for training. It can also give workers time for problem solving etc.
-
- **PART-TIME WORKERS**: seasonal work lends itself to part-time jobs because less skills are needed.

- **INVENTORIES**: firms produce goods in one period and sell them in another. Storage costs are needed!

- **SUBCONTRACTING**: acquire temporary capacity

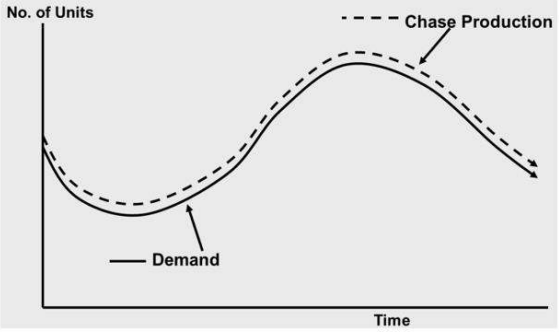
Basic strategies for meeting uneven demand

Prominent aggregate planning strategies are:

1. Maintain a level workforce (**level capacity**)
2. Maintain a steady output rate (**level capacity**)
3. Match demand period by period (**chase demand**)
4. Use a combination of decision variables

Level capacity strategy	Maintaining a steady rate of regular-time output while meeting variations in demand by a combination of options: inventories, overtime, part-time workers, subcontracting and back orders.
Chase demand strategy	Matching capacity to demand. The planned output for a period is equal to the expected demand for that period.

CHASE STRATEGY (ZERO INVENTORY PLAN)

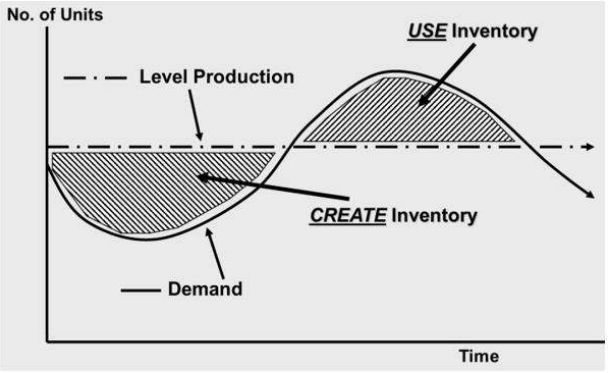


Capacities are adjusted to match demand.

ADV.
+ investment in inventory is low
+ labour utilization is high

DISADV.
- the cost of adjusting output rates and/or workforce levels

LEVEL STRATEGY (CONSTANT WORKFORCE PLAN)



Capacities are kept constant.

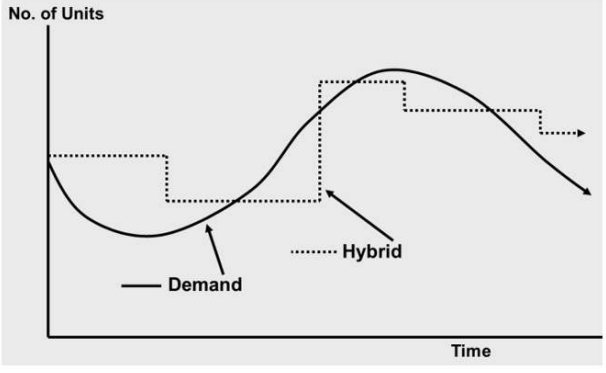
ADV.

+ stable output rates and workforce

DISADV.

- greater inventory costs
- increased overtime and idle time
- resource utilizations very over time

HYBRID STRATEGY (MIXED STRATEGIES)



You do not want to build up too much inventory, but you also don't want to have a lack of units. So at one point you are going to produce too much inventory, then you will slow it down a bit… Then start producing more again etc.

→ This is a solution in between chasing and levelling.

Whatever the strategy is, an organization is always considering three important factors: **policies, flexibility** and **costs**. Aggregate planners seek to match supply and demand within the constraints imposed on them by policies or agreements and at minimum costs. They usually evaluate alternatives in terms of their overall costs.

Aggregate planning techniques

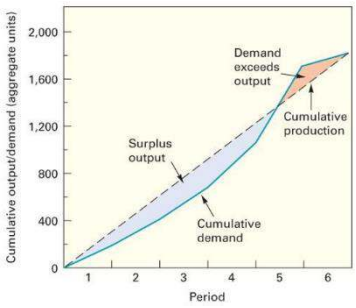
A general procedure for aggregate planning consists of the following steps:

1. Determine demand for each period
2. Determine capacities *(regular time, overtime, subcontracting)* for each period
3. Identify company or departmental policies that are pertinent *(e.g. maintain a safety stock of 5 percent, maintain a reasonably stable workforce, …)*
4. Determine unit costs
5. Develop alternative plans and compute the cost for each
6. If satisfactory plans emerge, select the one that best satisfies objectives

Trial-and-error techniques

Trial-and-error approach	Develop simple tables or graphs to enable planners to visually compare projected demand requirements with existing capacity.

→ Alternatives are evaluated in terms of their total costs
→ Disadvantage: the technique does not necessarily result in an optimal aggregate plan



The red part represents the costs that come from having a **backlog**.
→ Backordering is more expensive than keeping inventory.
So it is best if you keep the red part as small as possible!

Example on the trial-and-error technique, see slides!

Mathematical techniques

- **Linear programming (LP) models**: methods for obtaining optimal solutions to problems involving the allocation of scarce resources in terms of *cost minimization* or *profit maximization*.
  Constraints: - demand
  - conservation of inventory and workforce

- **Stimulation models**: computerized models that can be tested under different scenarios to identify acceptable solutions to problems.

Aggregate planning in services

Takes into account projected customer demands, equipment capacities and labour capabilities.

- **Hospitals**: aggregate planning to allocate funds, staff and supplies to meet demand of patients.

- **Airlines:** aggregate planning in this industry is fairly complex because it has to take into account, a wide variety of factors (planes, flight personnel, ground personnel) and multiple roads and landing/departure sites. Capacity decisions must also take into account the percentage of seats to be allocated to various fare classes (business, economic) in order to maximize profits or yields.

- **Restaurants**: directed towards smoothing the output rate, determining workforce size and managing demand to match a fixed capacity. This is the case for all high-volume businesses.
  → you can use inventory, but goods are perishable…

The resulting plan in services is a **time-phased projection** of service staff requirements. Aggregate planning in service and manufacturing industries is similar, but there are some key differences:

1. **Demand for service can be difficult to predict**
   In some situations customers *need* prompt service, in other situations they just *want* it and they may be willing to go elsewhere if their wants are met there.

2. **Capacity availability can be difficult to predict**
   A suitable measure for planning purposes can be hard to find when talking about services.

3. **Labour flexibility can be an advantage in services**
   Service providers are often able to handle a wide variety of service requirements.

4. **Services occur when they are rendered**
   Most services can't be inventoried. This removes the option of building up inventory during a slow period in anticipation of further demand.

Yield management

Yield management	It is an approach to maximizing revenue by using a strategy of variable pricing, prices are set relative to capacity availability.

→ during periods of low demand, price discounts are offered
→ during peak periods, higher prices are charged

Users of yield management include restaurants *(cheaper meals for people that come to dinner at 17 or 18 o'clock, cheaper meals for children etc.),* hotels and airlines.

Master scheduling

Disaggregating the aggregate plan

The result of disaggregating the aggregate plan is the **master schedule**. This shows the quantity and timing of **specific** end items for a scheduled horizon (<> product families in the aggregate plan).

Master scheduling is the **heart of production planning and control**.

→ It determines the quantity needed to meet demand from all sources.

→ The master schedule interfaces with:
- marketing
- capacity planning
- production planning
- distribution planning

→ It provides senior management with the ability to determine whether the business plan and its strategic objectives will be achieved or not.

Time fences

Changes to a master schedule can be disruptive, particularly changes to early portions of the schedule. The further out in the future a change is, the less the tendency to cause problems.

Time fences	Divide a scheduling time horizon into three sections, sometimes referred to as *frozen, slushy* and *liquid*.

- **Frozen**: the near-term phase that is so soon that delivery of a new order would be impossible or only possible using very costly options such as delaying another order.

- **Slushy**: order entry in this phase necessitates trade-offs, but is less costly or disruptive than in the frozen phase. There is relative confidence in order-promising dates and capacity planning becomes very specific.

- **Liquid**: new orders or cancellations can be entered with ease. Order promise dates are tentative, and will be firmed up with the passage of time when orders are in the firm phase of the schedule horizon.

A key element in the success of master scheduling process is strict adherence to time fence rules!

The master scheduling process

INPUTS: - *the beginning inventory*: the actual quantity on hand
- *forecasts* for each period
- *customer orders*: quantities already committed to customers

OUTPUTS: - *Projected inventory*:
- *master production schedule*
- *uncommitted inventory* = available-to-promise (ATP) inventory

- **The master production schedule (MPS)** is one of the primary outputs of the master scheduling process.
  → Once a *tentative* MPS has been developed, it must be validated

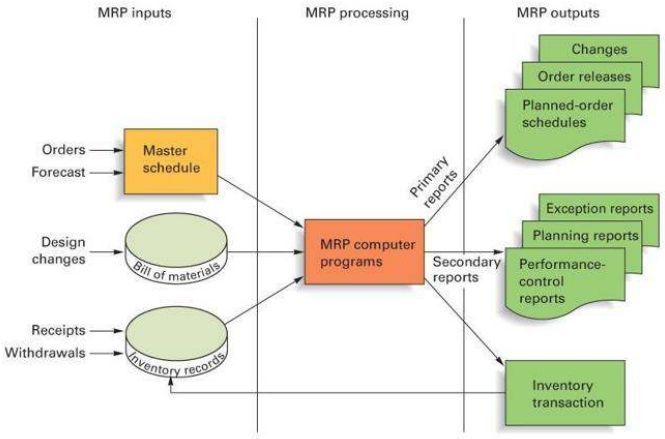
- **Rough cut capacity planning (RCCP)** is a tool used in the validation process
  → Approximate balancing of capacity and demand to test the feasibility of a master schedule
  → Involves checking the capacities of production and warehouse facilities, labour, and vendors to ensure no gross deficiencies exist that will render the MPS unworkable

Material requirements planning and ERP

MRP	= Material requirements planning A computer-based information system that translates master schedule requirements for end items, into time-phased requirements for subassemblies, components and raw materials.

The materials requirements planning (MPR) is designed to answer three questions:

1) What is needed?
2) How much is needed?
3) When is it needed?



MRP inputs

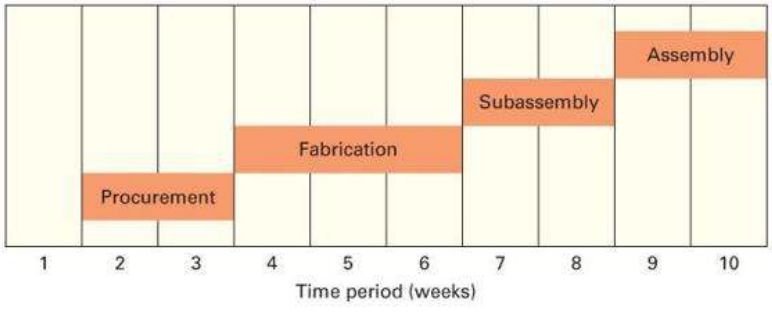
Master schedule

Master schedule	One of the 3 primary inputs. States which end items are to be produced, when these are needed and in what quantities.

The master schedule separates the planning horizon into a series of time periods or time buckets. The time buckets don't have to be of equal length. Most managers like to plan far enough into the future so they have reasonable estimates of upcoming demands.

It is important that the master schedule covers a period that is at least equivalent to the cumulative lead time necessary to produce end items.

Cumulative lead time	The sum of the lead times that sequential phases of a process require, from ordering of parts or raw materials to completion of final assembly.



Bill of materials (BOM)

Bill of materials	A listing of all of the assemblies, subassemblies, parts and raw materials needed to produce one unit of a product. Each finished product has its own bill of landing.

A bill of landing is the same as a **product structure tree**, the only difference is that a product structure tree is a visual depiction of the requirements in a bill of materials, where all components are listed by levels.

The end item is shown at the top of the tree, just beneath it are the subassemblies. At each stage moving down the tree are the components needed to make one unit of the next higher item in the tree. Items at the lowest level of the tree are often raw materials or purchased parts.

Low-level coding	Used when a component appears on more than one level. It restructures the bill of landing so that multiple occurrences of a component all coincide with the lowest level at which the component occurs.

The inventory records

Inventory records	Refer to stored information on the status of each item by time period, called *time buckets*.

Inventory records include information about: gross requirements, scheduled receipts and expected amount on hand.
But also other details for each item such as: Supplier, lead time, lot size policy, changes due to stock receipts and withdrawals and cancelled orders and similar events.

MRP outputs

Primary outputs

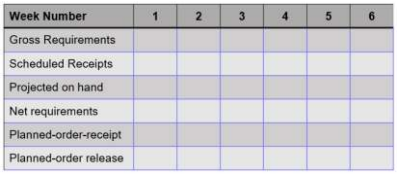
- **Planned orders:** a schedule indicating the amount and timing of future orders
- **Order releases:** authorizing the execution of planned orders
- **Changes**: to planned orders, including revisions of due dates or order quantities and cancellations

Secondary outputs

- **Performance-control reports**: Evaluation of system operation, including deviations from plans and cost information. *e.g., missed deliveries and stockouts.*
- **Planning reports**: Data useful for assessing future material requirements. *e.g., purchase commitments*
- **Exception reports**: Data on any major discrepancies encountered *E.g., late and overdue orders, excessive scrap rates, requirements for nonexistent parts*

MRP processing

MRP processing takes the **end item requirements** specified by the **master schedule** and "explodes" them into ***time-phased requirements*** for assemblies, parts, and raw materials offset by ***lead times.***



Week Number	1	2	3	4	5	6
Gross Requirements						
Scheduled Receipts						
Projected on hand						
Net requirements						
Planned-order-receipt						
Planned-order release						

Gross requirements	Total expected demand per item per period
Scheduled receipts	Open orders scheduled to arrive
Projected available / on hand	Expected amount of inventory on hand at the beginning of each time period
Net requirements	The actual amount needed in each time period
Planned-order receipts	Quantity expected to be received by the beginning of the period offset by lead time
Planned-order releases	Planned amount to order in each time period

Project inventory on hand for the current period

= planned receipts previous period – net requirements previous period + scheduled receipts current period

Net requirements for current period

= gross requirements for current period – projected on-hand inventory for current period

Pegging	The process of identifying the parent items that have generated a given set of material requirements for an item.

Pegging denotes working the process in reverse! It enables managers to determine which products will be affected if orders are late due to deliveries, quality problems and other problems. (see figure on slides)

Updating the system

A material requirements plan is **not a static document**. Because as time passes some orders get completed, others are near completion, new orders will have been entered, existing orders will have been altered (because of quality changes, delays or missed deliveries).

Schedules such as these have a **rolling horizon**. Which means that plans are updated and revised so that they reflect the moving horizon over time. Two basic systems used to update MRP records are:

- **Regenerative system**: approach that updates MRP records periodically
    - Essentially a batch system that compiles all changes that occur within the time interval and periodically updates the system.
    - A revised production plan is developed in the same way the original plan was developed.

- **Net-change system**: approach that updates MRP records continuously
    - The production plan is modified to reflect changes as they occur
    - Only the changes are exploded through the system

Other MRP considerations

Safety stock

Theoretically, inventory systems with dependent demand (MRP systems) should not require safety stock below the end item level. Safety stock is not needed because the manager can project precise usage quantities once the master schedule has been established because demand is not variable.

Practically, there may be exceptions. Variability may necessitate the strategic use of safety stock:

- A bottleneck process or one with varying scrap rates can cause shortages in downstream operations
- Shortages may occur if orders are late or fabrication or assembly times are longer than expected

→ these conditions lend themselves to the use of safety stock to maintain smooth operations!

When **lead times are variable**, the concept of ***safety time*** is often used.

Safety time	Scheduling orders for arrival or completions sufficiently ahead of their need so that the probability of shortage is eliminated or significantly reduced.

It is important in general to make sure that lead times are accurate, particularly when the objective is to have incoming shipments of parts and materials arrive shortly before they are needed.

Lot sizing

LOT-FOR-LOT ORDERING (L4L)

The order or run size for each period is set equal to the demand in that period. (I am going to produce exactly what I need)

→ the order size is obvious and it minimizes investment in inventory.

Two drawbacks are that it usually involves many different order sizes (variable order quantities) and thus cannot take advantage of the economies of fixed order size. The other drawback is that it requires new setup costs for each production run.

ECONOMIC ORDER QUANITITY MODEL (EOQ)

They can lead to minimum costs if usage is fairly uniform.

→ this may be the case for lower-level items that are common to different 'parents'

→ less appropriate for lumpy demand items because the mismatch in supply and demand results in leftover inventories

FIXED-PERIOD ORDERING

This provides coverage for some predetermined number of periods.

→ A simple rule is: order to cover a two-period interval. The rule can be modified when common sense suggests a better way.

MRP benefits, requirements and difficulties

Benefits

MRP enables managers to easily

- determine the quantities of each component for a given order size
- To know when to release orders for each component
- To be alerted when items need attention

Additional benefits are:

- Low levels of in-process inventories
- The ability to track material requirements
- The ability to evaluate capacity requirements
- A means of allocating production time
- The ability to easily determine inventory usage via ***backflushing***

Backflushing	Exploding an end item's Bill Of Materials to determine the quantities of the components that were used to make the items.

The benefits of MRP depend in large measures on the use of a computer to maintain up-to-date information on material requirements.

Requirements

In order to implement and operate an effective MRP system, it is necessary to have:

1. A computer + necessary software programs to handle computations and maintain records
2. Accurate and up-to-date:
   - Master schedules
   - Bills of materials
   - Inventory records
3. Integrity of file data

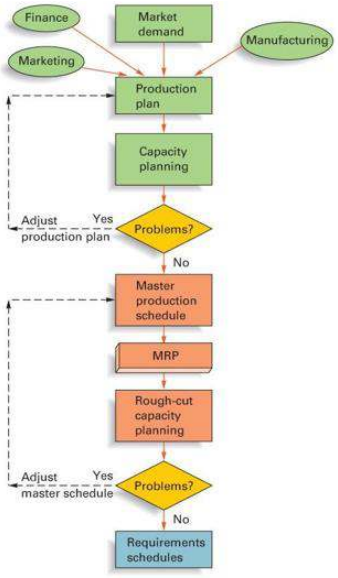
Difficulties

Accuracy is absolutely essential for a successful MRP system. Inaccuracies can cause inefficient use or resources:

- Missing parts
- ordering too many items of some and too few of others
- failure to stay on schedule

Other common problems are:

- Assumption of constant lead times
- Products being produced differently from the BOM
- Failure to alter a BOM when customizing a product
- Inaccurate forecasts



MRP II

MRP was developed as a way for manufacturing companies to calculate more precisely what materials were needed to produce a product, and when and how much of those materials were needed.

Manufacturing resource planning (MRP II) expanded approach to production resource planning, involving other areas of the firm in the planning process and enabling capacity requirements planning.

→ Most MRP II systems have the capability of performing simulation to answer a variety of "what if" questions so they can gain a better appreciation of available options and their consequences

Closed loop MRP

When MRP was introduced, it did not have the capability to assess the feasibility of a proposed plan. So there was no way of knowing before executing the proposed plan if it could be achieved, or after executing the plan if it had been achieved. → A new plan had to be developed each week

MRP II systems began to include **feedback loops**, referred to as **closed-loop MRP.**

Closed-loop MRP systems	Evaluate a proposed material plan relative to available capacity.

If a proposed plan is not feasible, it must be revised. This evaluation is referred to as capacity requirements planning.

Capacity requirements planning

One of the most important features of MRP II is its ability to aid managers in capacity planning.

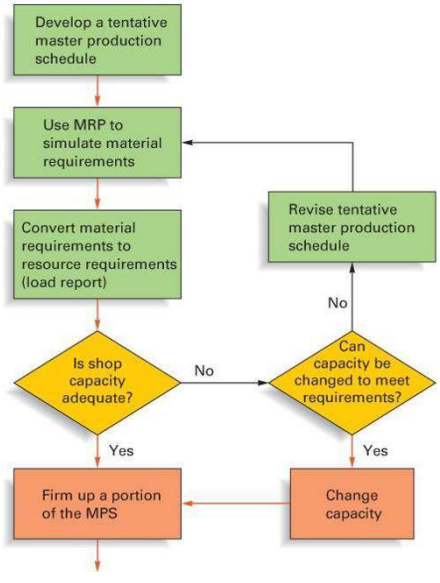
Capacity requirements planning	The process of determining short-range capacity requirements.

INPUTS to capacity requirement planning:

- Planned-order releases for the MRP
- Current shop loading
- Routing information
- Job time

Key OUTPUTS :

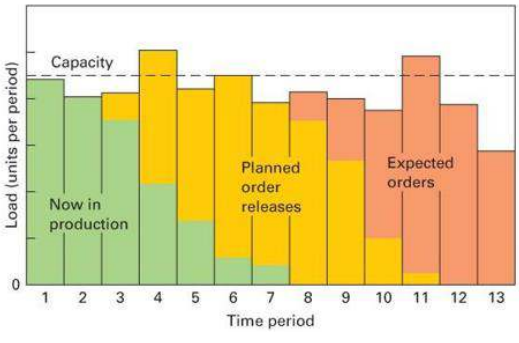
- Load reports for each work center



The capacity planning process begins with a proposed or tentative master production schedule that must be tested for feasibility and possible adjusted before it becomes permanent.

The proposed schedule is processed using MRP to ascertain the material requirements the schedule would generate. These are then translated into resource requirements, often in the form of a series of **load reports** for each department or work centre.

Load report	Department or work centre reports that compare known and expected future capacity requirements with projected capacity availability.



On load reports you can see if you have spare capacity or if you have a lack of capacity.

MRP with capacity constraints

Do you have an infeasible or a feasible problem?

→ feasible: is lot-of-lot possible? Yes, ok good

→ No: construct a new requirements schedule r' where L4L is feasible

Improve the feasible solution by shifting, starting from the last period and working backwards to the beginning.

Enterprise Resource Planning (ERP)

Enterprise resource planning	Integration of financial, manufacturing and human resources in a single database.

ERP was the next step in an evolution that began with MRP and evolved into MRP II.
ERP, like MRP II, typically has an MRP core. It provides a system to capture and make data available in real time to decision makers and other users throughout an organization. It also provides a set of tools for planning and monitoring various business processes to achieve the goals of an organization. ERP systems are composed of a collection of integrated modules.

ERP project organization

- ***The 'big bang'***
  - Companies cast off all of their legacy systems at once and implement a single ERP system across the entire company
  - The most ambitious and difficult implementation approach
- ***Franchising strategy***
  - Independent ERP systems are installed in each business unit of the enterprise while linking common processes across the enterprise
  - Suits large or diverse companies that do not share many common processes across business units
- ***Slam Dunk***
  - ERP dictates the process design where the focus is on a few key processes
  - More appropriate for smaller companies expecting to grow into ERP

ERP considerations

- How can ERP improve a company's business performance?
- How long will an ERP implementation project take?
- How will ERP affect current business processes?
- What is the ERP total cost of ownership?
- What are the hidden costs of ERP ownership?

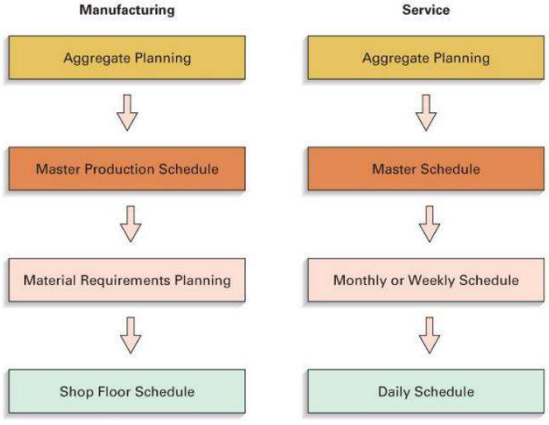
→ read in text page 313

Scheduling

Scheduling	Establishing the timing of the use of specific resources of that organization.

It relates to the use of equipment, facilities and human activities. In the decision-making hierarchy, scheduling decisions are the final step in the transformation process before actual output occurs.
Effective scheduling can yield:

- Cost savings
- Increases in productivity
- Other benefits



In this chapter we are going to look at scheduling on a **daily basis**.

Scheduling is constrained by multiple system design and operations decisions

- System capacity & equipment selection
- Product and/or service design
- Worker selection and training
- Aggregate planning and master scheduling

High-volume systems and intermediate-volume systems

High-volume systems

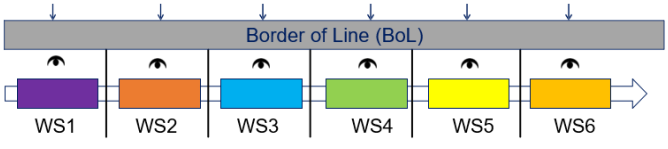
Flow systems	High-volume systems in which all jobs follow the same sequence
Flow system scheduling	Scheduling for flow systems.

The GOAL of flow system scheduling is to obtain a smooth rate of flow goods or customers through the system in order to get a high utilization of labour and equipment.

Few flow systems are entirely dedicated to a single product or service.
Each product change requires:

- Slightly different inputs of parts
- Slightly different materials
- Slightly different processing requirements that must be scheduled into the line

To achieve a smooth flow, it is important to avoid excessive build-up of inventories. Disruptions may result in less-than-desired output so you have to avoid those.



Mixed-model product layout: Here you have different product models, every different colour is a different product variant. From the moment that one workstation has problems, the other workstations also have problems. → Based on what happens to your balance you have to switch the sequence of your model variants.

Each product variant requires different **task times t_{jk}** with task j on model k. Then there is also **line balancing**: which concerns allocating the required tasks to workstations so that they satisfy technical constraints and are balanced with respect to equal work times among stations. In some cases the line may be *overloaded*.

The following factors often determine the success of such a system:

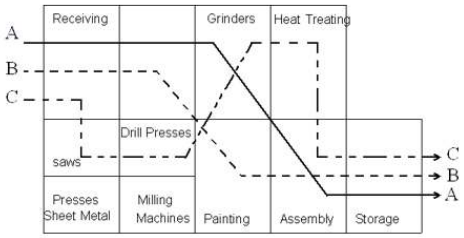
- **Product and process design**: cost and manufacturability are important
- **Preventive maintenance**: keep equipment in good operating order to minimize breakdowns
- **Rapid repair when breakdowns occur**
- **Optimal product mixes**: determine optimal blends of inputs to achieve desired outputs and costs.
- **Minimization of quality problems**: to reduce the loss of output and waste of labour, materials, time
- **Reliability and timing of supplies**

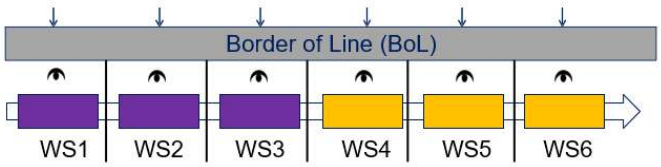
Intermediate-volume systems

The output falls between the standardized type of output of the high-volume systems and made-to-order output of job shops. However, the output rates are insufficient to warrant continuous production. Instead, it is more economical to process these items **intermittently**.

To work intermittently	Work centres periodically shift from one product to another

Process layout or **multi-model product layout**





The three basic issues in these systems are:
- **run size** of jobs
- **timing** of jobs
- **sequence** in jobs should be processed

The run size that minimizes setup and inventory costs is: $Q_p = \sqrt{\frac{2DS}{H}}\sqrt{\frac{p}{p-u}}$ (S = setup cost)

Important considerations:
- Setup cost: this may depend on the order in which jobs are processed.
- Usage is not always as smooth as assumed in the economic lot size model: some products will tend to be used up faster than expected and have to be replenished sooner.

Scheduling in low-volume systems (job shops)

Job-shop scheduling	Scheduling for low-volume systems with many variations in requirements. This is usually fairly complex.

The characteristics of low-volume systems are:
- Products are made to order
- Orders differ in:
  - Processing requirements
  - Materials needed
  - Processing time
  - Processing sequence and setup

Job shops provide a complex scheduling environment because it is impossible to establish firm schedules until actual job orders are received.

Loading

Loading	The assignment of jobs to processing centres. Loading decisions involve assigning specific jobs to work centres and to various machines in the work centres.

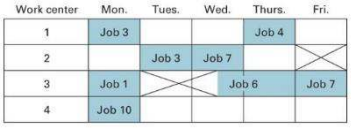
Gantt Chart

Gantt Chart	Chart used as visual aid for loading and scheduling purposes.

The purpose of the Gantt chart is to organize and visually display the actual or intended use of resources in a time framework. Managers may use the charts for trial-and-error schedule development to get an idea of what different arrangements would involve.

There are a number of different types of Gantt charts, two of the most commonly used are:

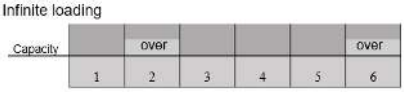
- **LOAD CHART**
  A Gantt chart that shows the loading and idle times for a group of machines or a list of departments. A load chart is a gantt chart from the LOADING PERSPECTIVE.



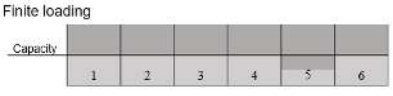
Loading approaches

Two different approaches can be used to load work centres:

- **Infinite loading**: jobs are assigned to workstations without regard to the capacity of the work centres.



- **Finite loading**: jobs are assigned to workstations taking into account the work centre capacity and job processing times.

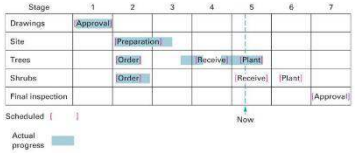


Scheduling approaches

- **Forward scheduling**: scheduling ahead from a point in time. This is used when you have to ask the question: "*How long will it take to complete this job?"*
  → pushing

- **Backward scheduling**: scheduling backward from a due date. This is used when the question is: "*When is the latest this job can be started and still be completed on time?"*
  → pulling

- **SCHEDULE CHART**
  A Gantt chart that shows the orders or jobs in progress and whether they are on schedule.



Assigning

Assignment model	A linear programming model for optimal assignment of tasks and resources.

I'm going to assign something to something else. → many different things can be assigned

Typical examples include: *assigning jobs to machines or workers, territories to salespeople and repair jobs to repair crews.*

Hungarian method	An optimal method of assigning jobs by a one-for-one matching to identify the lowest-cost solution.

→ One-for-one matching means that each job must be assigned to only one worker. Also the number of columns and rows must be the same.

The six steps to follow are on the slides!

Sequencing

Sequencing	Determining the order in which jobs at a work centre will be processed
Priority rules	Simple heuristics used to select the order in which jobs will be processed
Job time	Time needed for setup and processing of a job

Typically, a number of orders will be waiting for processing. Priority rules are then used to determine the order in which they will be processed. The rules generally rest on the assumption that job setup cost and due dates are important pieces of information.

Some of the most common **priority rules** are:

- **FCFS (first come, first served)**: jobs are processed in the order in which they arrive at a machine
- **SPT (shortest processing time)**: jobs are processed according to processing time at a machine
- **EDD (earliest due date)**: jobs are processed according to due date (earliest first)
- **CR (critical ratio)**: jobs are processed according to the smallest time ratio of time remaining until due date to processing time remaining.

A number of assumptions that apply when using the priority rules are:

- The set of jobs is known; no new orders arrive after processing begins & no jobs are cancelled
- Setup time is independent of processing sequence
- Setup time is deterministic
- Processing times are deterministic
- There will be no interruptions in processing such as machine breakdowns or accidents

The effectiveness of any given sequence is frequently judged in terms of one or more ***performance measures***. The most frequently used performance measures are:

- **Job flow time**
  This is the amount of time it takes from when a job arrives until it is complete. It includes not only processing time but also any time waiting to be processed or transportation time.

- **Job lateness**
  Difference between completion time and due date (may be negative).

- **Job tardiness**
  The positive difference between the completion time and the due date (no negative numbers are allowed . If you have a positive number e.g. 5 then that means you are 5 days late. If you are 5 days early the job tardiness isn't -5 but it is 0).

- **Makespan**
  The total time needed to complete a ***group*** of jobs from the beginning of the first job to the completion of the last job.

- **Average number of jobs**
  Jobs that are in a shop are considered to be WIP (work-in-process) inventory. The average WIP for a group can be computed as: **AVG number of jobs = total flow time / makespan**

Scheduling rules

- The total **makespan** is independent of the sequencing algorithm
- The rule that minimizes mean flow time of all jobs the most is **SPT**
- The following criteria are equivalent:
  → mean job flow time
  → mean waiting time
  → mean lateness
- Minimize maximum lateness with **EDD**
- The **CR** rule usually does quite well in terms of minimizing job tardiness

Sequencing jobs through two work centres

Johnsons's rule	Is a technique that managers can use to minimize the makespan for a group of jobs to be processed ***on two machines*** or at ***two successive work centres***.

It minimizes the total idle time at the work centres. But for the technique to work, several conditions must be satisfied:

- Job time (including setup and processing) must be known and constant for each job at each work centre
- Job times must be independent of the job sequence
- All jobs must follow the same two-step work sequence
- A job must be completed at the first work centre before the job moves on to the second work centre

Application of Johnson's rule begins with a listing of all jobs to be scheduled, and how much time will be required by each job at each workstation. The sequence is determined by a number of steps which you can find on the slides + an example.

The theory of constraints (ToC)

Theory of constraints	A production planning approach that emphasizes balancing flow throughout a system, and pursues a perpetual five-step improvement process centered around the system's currently most restrictive constraint

Goldratt (who invented the theory) avoided much of the complexity often associated with scheduling problems by simply focusing on **bottleneck operations**. The output of the system was limited by the output of bottleneck operations, therefore it was essential to schedule the **nonbottleneck operations** in a way that minimizes the idle time of the bottleneck operations.

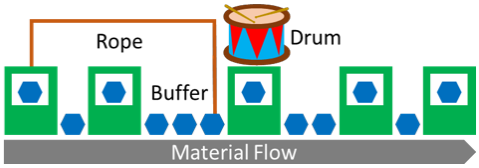
DRUM-BUFFER-ROPE conceptualization

DRUM: the schedule, it sets the pace of production.
→ the goal is to make maximum use of bottleneck resources

BUFFER: refers to potentially constraining resources outside of the bottleneck.
→ the role is to keep a small amount of inventory ahead of bottleneck operation to minimize the risk of having it be idle

ROPE: represents the synchronizing of the sequence of operations to ensure effective use of bottleneck operations.
→ avoid costly and time-consuming multiple setups so they do not become bottlenecks too. Do not produce what is not needed, only build what your bottleneck operation can follow.

The drum-buffer-rope approach provides a basis for developing a schedule that achieves maximum output and shorter lead times while avoiding carrying excess inventory.



Goldratt also developed a **SYSTEM OF VARYING BATCH SIZES** to achieve the greatest output of bottleneck operations:

- **Process batch**: the economical quantity to produce upon the activation of a given operation (the basic lot size for a job).
- **Transfer batch**: the quantity to be transported from one operation to another, assumed to be smaller than the first operation's process batch. (a portion of the basic lot that could be used during production to facilitate utilization of bottleneck operations.)

It's not because your process batch is 100 units big that you have to stick to that for your transfer batch as well, because it's better to work with smaller transfer batches. The smaller the transfer batch the better. But then again large process batches are preferred over small ones.

→ You have to think: what can I do to achieve the greatest efficiency on my bottleneck operations

(<> *Johnson's rule: only works when you process the entire job as a full job, without splitting it up.)*

Theory of constraints has as its goal maximizing flow through the entire system, which it does by emphasizing balancing the flow through the various operations. It begins with **identifying** the **bottleneck operation**. Next, there is a five step procedure to improve the performance of the bottleneck operation:

1) Determine what is constraining the operation
2) Exploit the constraint (i.e. make sure the constraining resource is used to its maximum)
3) Subordinate everything to the constraint (i.e. focus on the constraint)
4) Determine how to overcome the constraint (eliminate it)
5) Repeat the process for the next highest constraint

The GOAL of course is to **make more money!** The ToC uses three metrics to assess the effectiveness of improvements:

- **Throughput**
  The rate at which the system generates *money* through sales.
- **Inventory**
  Inventory represents *money* tied up in goods and materials used in a process
- **Operating expense**
  All the *money* the system spends to convert inventory into throughput, this includes utilities, scrap, depreciation and so on.

Scheduling on services

Problems

Scheduling service systems presents certain problems not generally encountered in manufacturing systems. This is due primarily to:

1. the inability to store or inventory services
2. the random nature of customer requests for service

The approach used to schedule services generally depends on whether customer contact is involved. The goal is to maximize worker efficiency, and work is often processed in batches. Having too few workers causes waiting lines to form, but having more workers than needed increases labour costs which can have a substantial impact on profits.

An ideal situation is one that has a smooth flow of customers through the system. This would occur if each new customer arrives at the precise instant that the preceding customer's service is completed. Then customer waiting time would be minimized and the service system staff and equipment would be fully utilized.

Scheduling in service systems may involve scheduling:
- **customers**
- the **workforce**
- **equipment**

Operations

Scheduling customers: demand management

- **APPOINTMENT SYSTEMS**
  To control the timing of customer arrivals in order to minimize customer waiting while achieving a high degree of capacity utilization.

  E.g. a doctor can use an appointment system to schedule patients' office visits in the afternoon, leaving the mornings free from hospital duties.

- **RESERVATION SYSTEMS**
  Designed to enable service systems to formulate a fairly accurate estimate of the demand on the system for a given time period, to minimize customer disappointment generated by excessive waiting or inability to obtain service.

  Widely used by hotels, restaurants, some modes of transportation (e.g. airlines, cars, …)

Scheduling workforce: capacity management

- **CYCLE SCHEDULING**
  Employees are assigned to work shifts or time slots, and have days off, on a repeating basis.

Chapter 8: Transportation

Transportation is the largest expenditure in logistics. Transportation managers are responsible for moving inventory throughout a firm's supply chain and to customers. Precise product delivery helps a firm reduce inventory, storage and materials handling.

- The value of transportation service is greater than simply moving a product
- There is no such thing as cheap transportation

Transport functionality and participants

Functionality

Transportation provides two major logistical services: product movement and product storage.

Product movement

The basic value provided by transportation is to move inventory to specified destinations throughout the supply chain. It also plays a key role in the performance of reverse logistics: without reliable transportation, most commercial activity could not function. But, it consumes time, financial and environmental resources.

TIME

Transportation has a **restrictive element** because inventory is inaccessible during transportation. Managers try to reduce in-transit inventory as much as possible. And advancements in technologies helped them to improve this.

In-transit inventory	Inventory captive in the transportation system.

FINANCIAL RESOURCES

Costs result from driver labour, fuel, vehicle maintenance, equipment, administration… Also product loss and damages can result in extra costs.

ENVIRONMENTAL RESOURCES

Transportation represents one of the largest consumers of oil and fuel in the U.S. economy. Indirectly, it impacts the environment through air pollution, noise pollution and congestion.

Product storage

When a product is in transportation, it is stored in the vehicle. Transport vehicles can be used for temporary storage at the shipment or origin destination. *If the products need to be shipped within a few days then it might be cheaper to store them in the vehicle instead of unloading, storing and reloading them again!*

Then you also have **diversion**. Even though it is costly, product storage in vehicles may be justified from a total cost or performance perspective when loading or unloading costs, capacity constraints and ability to extend lead times are taken into consideration.

Diversion	The original shipment destination is changed after the product has been shipped.

Participants

Transportation decisions are influenced by six parties:

- **Shipper/consignor**
- **Destination party / consignee**

The consignor and the consignee have a common interest: completing a sale or purchase transaction. Successful transactions are bringing the good to the right location, within a specified time at the lowest possible cost.

- **Carriers and agents**
  A business that performance a transportation service. They want to charge their customers the highest possible rate while minimizing labour, fuel and vehicle operating costs.

- **Government**

  They desire a stable and efficient transportation environment to support economic growth. This requires that carriers provide essential services at reasonable costs. Governments have been very involved in oversight of carrier operating and pricing practices, because transportation is so important for the economy. Governments used to restrict the markets that carriers could serve and approved prices that could be charged.

- **Internet**

  Carriers can share real time information with customers and suppliers. In addition, a wide variety of web based enterprises established, they typically provide two types of marketplaces.
  - Marketplace to exchange information for matching carrier capacity with available shipment
  - Marketplace for purchasing fuel, equipment, parts and supplies.

- **The public**

  They are concerned with transportation accessibility, effectiveness and expense. As well as environmental protection (oil spillage, air pollution), security and safety. The public indirectly creates transportation demands by purchasing goods.

Transportation policy formation is complex because of the interaction between these 6 participants. This results in frequent conflicts.

From regulation to a free market system

Government has historically taken a special interest in both controlling and promoting transport development. This involvement has taken the form of federal and state regulations as well as a wide range of judicial administration.

Transportation model structure

Freight	goods transported in bulk by truck, train, ship, or aircraft.

The freight transportation structure consists of the rights-of-way, vehicles and carriers that operate within five basic transportation **modes**: rail, truck, water, pipeline and air.

Mode	Identifies a basic transportation method or form.

As the data on page 518 in the book shows, the **truck share** of the domestic freight market far exceeds that of all other modes combined. BUT all transport modes are vital for a good national transportation structure.

Rail

Railroads used to rank first among all modes, but then came the development of roads and highways and the growth of automobiles and trucks changed this ranking. The main reason to keep using railroads is the **capability to efficiently transport large tonnage over long distances**.

- *High fixed costs*: bc of expensive equipment, terminals, switching yards
- BUT they enjoy *relative low variable operating costs*

Core railroad tonnage comes from bulk materials for which water transport is not available, heavy items such as cars, farm equipment and machinery.

Significant changes continue to occur in tradition railroading, in order to retain and grow railroad market share.

Truck

Trucks have flexibility because they are able to operate on a variety of roadways. But truck operations are characterized by **low fixed and high variable costs**:

- A *small fixed investment* in terminals compared to trains, plus they operate on publicly financed and maintained roads.
- License fees, user fees and tolls are considerable. The variable cost per mile for motor carriers is high because of separate power unit and driver requirements. Labour requirements are also high because of driver safety restrictions and need for substantial dock labour.

In comparison to railroads, motor carriers handle small shipments more efficiently when moving of a short distance.

PROBLEMS: increasing cost to replace equipment, maintenance, safety, driver shortages, driver hours-of-service regulations etc.

You have **for-hired** truck service, but you also have **shipper-owned** trucks or trucks that are operated by **integrated logistics service providers (ISPs)** that are under contract to perform transport services for specific shippers

ISP	Offers a service that combines flexibility of private with the consolidation potential of shared for-hired operators. An ISP may perform services for multiple shippers and thus gain both economies of scale and distance.

The industry segments of for-hired trucking include:

- **truckload** (**TL**): loads over 15.000 pounds that do not require stops between origin and destination
- **less-than-truckload** (**LTL**): shipments less than 15.000 pounds, this has a higher percentage of fixed costs compared to TL
- **specialty:** bulk and package haulers such as Waste Management and United Parcel Service (UPS). They focus on specific transport requirements of a market or product.

Water

A distinction is generally made between deepwater and navigable inland water transport. Domestic water transport involves the Great Lakes, canals and intracoastal waterways. Water transport employs two types of vessels:

- Deepwater vessels: for coastal, ocean and Great Lake transport
- Diesel-towed barges: operate on rivers and canals and have considerably more flexibility

Main advantage: you have the capacity to transport extremely large shipments.
Main disadvantage: there is a limited range of operations and a slow speed.

But the slow transit time provides a form of product storage in transit that can benefit logistics system operations. Plus, water transport ranks between truck and rail in term of fixed costs.

Pipeline

Mostly petroleum is transported by pipeline but other than that also natural gas. Pipelines are privately owned and operated.

Main advantage: Pipelines operate 24/7, they are limited only by commodity changeover and maintenance. And they have low variable costs because they are not labour intensive.
Main disadvantage: they have the highest fixed costs due to construction, requirements for control stations and pumping capacity. They are not flexible and they can only transport liquid, gas or slurry.

Air

Main advantage: speed. The speed allows other aspects of logistics such as warehousing and inventory to be reduced or eliminated. Also the fixed costs are low since airplanes are produced and maintained by the government.
Main disadvantage: extremely high variable costs, as a result of fuel, user fees, maintenance, labour intensity but also the significant real estate required by airports…

When the marketing for a product is extremely limited then air may be the only transportation method to support global routines.

Model comparative characteristics and capabilities

The five modes are ranked based on:

- **Speed**: elapsed movement of time. Airfreight is the fastest!
- **Availability:** ability of a mode to serve any given pair of locations. Highway carriers have the highest availability since they can drive directly to destination points.
- **Dependability**: potential variance from expected or published delivery schedules. Pipelines have the highest dependability because they are not influence by weather conditions etc.
- **Capability**: ability to handle any transport requirement, such as load size. Water transport is most capable.
- **Frequency**: the quantity of scheduled movements. Pipelines have the highest frequency, again because of their continuous service between two points.

SUMMARY

- **Rail**: high fixed cost in equipment, terminals, tracks etc. Low variable cost.
- **Truck**: low fixed cost (highways in place and provided by public support). Medium variable cost (fuel, maintenance, etc.)
- **Water**: medium fixed cost (ships and equipment). Low variable cost (capability to transport large amount of tonnage).
- **Pipeline**: highest fixed cost (right-of-ways, construction, requirements for control stations and pumping capacity). Lowest variable cost (no labour cost of any significance).
- **Air:** low fixed cost (aircrafts and handling and cargo systems). High variable cost (fuel, labour, maintenance, etc.)

Specialized transportation services

Transportation services can be improved by combining modes. In what follows we discuss the range of specialized services offered by different carriers:

PACKAGE SERVICE

Due to overhead costs motor carriers implemented a **minimum charge**, the minimum applies to all shipments regardless of shipment size or distance. As a result of the minimum charge, companies started to offer specialized service to enter the small-shipment or package-serving market.

Packages are usually transported using the line-haul services of air, rail and motor. Package service provides both regular and premium services. Example of carriers: FedEx, UPS, USPS.

INTERMODAL

Intermodal transportation combines two or more modes to take advantage of inherent economies of each and thus provide an integrated service at lower total cost.

Piggyback	Combines the flexibility of truck for short distances with low line-haul cost associated with rail for longer distances.

→ The popularity of such offerings has increased significantly as a means to achieve more efficient and effective transportation. Intermodal transportation can be arranged among all basic modes.

TOFC/COFC

Trailer on a flatcar (TOFC) and container on a flatcar (COFC). Containers are boxes used for intermodal product storage and movement between motor freight, railroads and water transportation. Trailers have a similar weight and height as containers but are longer and have highway wheels.

A trailer or container is placed on a flatcar for some portion of intercity line-haul and pulled by a truck at origin and to the final destination. TOFC facilitates direct transfer between rail and motor carriage, but it also has several technical limitations. The use of containers reduces the potential problems.

Line-haul cost	The expense to move railcars or trucks between cities.

CONTAINERSHIP

They utilize waterways which are one of the least expensive modes for line-haul movement. The fishyback, trainship and containership concept loads a truck trailer, railcar or container onto a barge of ship for the line-haul movement on island navigable waterways.

A variant of this intermodal option is the **land bridge** concept that moves containers in a combination of sea and rail transport. It is based on the benefit of ocean and rail combinations that utilize a single tariff, which is lower than the combined total cost of two separate rates.

NONOPERATING INTERMEDIARIES

There are several businesses that do not own or operate equipment. These nonoperating intermediaries arrange services of other firms.

Transportation broker	Somewhat similar to a wholesaler in a marketing channel.

Nonoperating intermediaries find economic justification by offering shippers lower rates for movement between two locations than would be possible by direct shipment via common carriers. Sometimes nonoperating intermediaries charge higher rates but that is based on the ability to arrange faster delivery and/or more value-added services.

- FREIGHT FORWARDERS

  For-profit businesses that bring together small shipments from various suppliers into a bulk shipment and ships them together. At destination, the freight forwarder splits the shipment into original smaller shipments. Local delivery may or may not be arranged by the freight forwarder.

- SHIPPER ASSOCIATIONS

  Operate in the same way as freight forwarders but they are voluntary non profit entities where the members, operating in a specific industry, collaborate to gain economies related to small-shipment purchases. They consolidate their small purchases into large movements to gain cost economies.

- BROKERS

  Coordinate transportation arrangements for shippers, consignees and carriers. Brokers typically operate on a commission basis, they provide extensive services such as shipment matching, rate negotiations, billing and tracing.

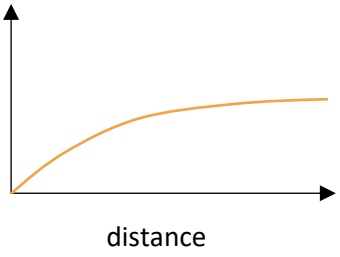
Transportation economics and pricing

The primary factors that drive transportation economics and pricing are: distance, weight and density.

1. Economies

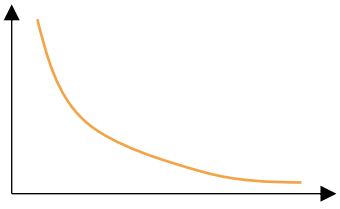
Economy of distance

Distance directly contributes to variable expense, such as labour, fuel, maintenance. The cost curve does not begin at zero because there are fixed costs associated with shipment pickup and delivery regardless of distance. The cost curve increases at a decreasing rate as a function of distance. This is known as the **tapering principle.**



Economy of weight

Transport cost per unit of weight decreases as load size increases, because the fixed costs of pickup, delivery and administration spread of incremental weight. This relationship is limited by the size of the transportation vehicle. Small loads should be consolidated into larger loads to maximize scale economies.



Economy of density

Density is the combination of weight and volume. Higher-density products allow fixed transport cost to be spread across more weight. As a result, higher density products are typically assessed lower transportation costs per unit. (see graph p. 530)

Other pricing factors

- **Stowability**: odd package sizes and shapes, as well as excessive size or length, may not fit well in transportation equipment, resulted in wasted cubic capacity.

- **Handling**: special handling equipment may be needed to load and unload trucks, trains or ships. It can impact handling costs if you group products together in boxes or on pallets for transport and storage.

- **Liability**: some product characteristics can result in damage. By improved packaging or reduced susceptibility to loss or damage, shippers can reduce their risk of damaging the goods.

- **Market**: market factors such as lone volume and balance influence transportation cost. Transportation vehicles and drivers usually return to their origin, so they must either find a **back-haul** load or the vehicle is returned or **deadheaded** empty. For empty returns you also have to pay fuel, labour, maintenance etc. Thus the ideal situation is to achieve two-way or balanced movement of loads.

Transport lanes	Movements between origin and destination points

2. Costing freight

- **VARIABLE**

Costs that change in relation to some level of activity. They include direct carrier costs associated with movement of each load. The expenses are mostly measured as a cost per mile or per unit of weight.

- **FIXED**

Expenses that do not change in the short run and must be paid even when a company is not operating. This includes costs not directly influenced by shipment volume.

- **JOINT**

Expenses created by the decision to provide a particular service. Joint costs have significant impact on transportation charges because carrier quotations must include implied joint costs based on assessment of back-haul inventory. (when a carrier takes a load from point A to B, there is a decision to incur a **joint** cost for the back-haul from point B to A. this must be covered by the original shipper or a back-haul shipper must be found.)

- **COMMON**

Carrier costs that are incurred on behalf of all or selected shippers. They are often allocated to a shipper according to the level of activity like the number of shipments or delivery appointments handled.

3. Pricing freight

…

Transportation management

Transportation management systems (TMS)	Proactively identifies and evaluates transportation strategies and tactics to determine the best methods to ship products. TMS creates reduced costs and the ability to provide on-time delivery.

Typical TMS functionalities:
- select transport modes
- plan loads
- consolidate shipments
- route optimization
- efficiently use transportation capacity

The generalized functionality can be described in terms of:
1) operational management
2) consolidation
3) negotiation
4) control
5) auditing and claims administration

1. operational management

- **EQUIPMENT SCHEDULING AND YARD MANAGEMENT**

Not planning well may lead to operational bottlenecks, so that your equipment has to wait to be loaded or unloaded. Yard management requires careful load planning, equipment utilization and driver scheduling. It is also important to plan the delivery and pickup appointments properly, to avoid extensive waiting time and to improve equipment utilization.

- **LOAD PLANNING**

How loads are planned impacts transportation efficiency. Planning the load must consider physical characteristics and size of individual shipments, as well as delivery sequence if multiple shipments are loaded in one single trailer.

- **ROUTING AND ADVANCED SHIPMENT NOTIFICATION (ASN)**

ASN is used to allow adequate time to plan arrival, arrange delivery appointments and plan to redeploy the shipment's content. How deliveries are planned must take into consideration special requirements of customers in terms of time, location and special unloading services.

- **MOVEMENT ADMINISTRATION**

Effective administration requires continuous carrier performance measurement and evaluation. Effective administration requires carrier selection, integration and evaluation.

2. Consolidation

Traffic management is the business function responsible for achieving freight consolidation. The transportation savings in moving a single consolidated shipment vs. multiple individual, small shipments were typically sufficient to pay for necessary handling and local delivery while achieving significant total cost reduction.

→ All members of the supply chain want to reduce the time that goods stay in inventory by more closely synchronizing replenishment with demand. The result is more frequent, small orders. This increases smaller shipments, but it also increases transportation costs!

All aspects of consolidation require **timely and relevant information** concerning planned activities!

Reactive consolidation

Reactive consolidation	Doesn't try to influence the composition and timing of transportation movements. The consolidation effort reacts to shipments as they come and seeks to combine individual orders into larger shipments.

There are three ways to achieve effective reactive consolidation:

i. **Market area**: combine small shipments going to different customers within a geographical market area

ii. **Scheduled area delivery**: holding shipments to specific markets for delivery on selected days.
→ consolidated shipments may be sent to an intermediate break-bulk point.
There, individual shipments are separated and forwarded to their destination.
→ firms can choose to hold consolidated shipments for scheduled deliveries on specific days to given destination markets.
→ utilize the services of a 3-PL firm to pool delivery

iii. **Pooled delivery**: freight forwarder, public warehouse or transportation company arranges consolidation for multiple shippers serving the same geographical market area. It is common for the consolidation company to also perform value-added services to accommodate customer requirements.

Proactive consolidation

Proactive consolidation	Reflects the desire for shippers and carriers to participate in consolidation savings.

Response-based logistical systems create a larger number of small shipments. This trend towards smaller shipments has been intensified by e-commerce.

An important step towards achieving proactive consolidation is **preorder planning** of quantity and timing to facilitate consolidated freight movement. The creation of orders should not be restricted to standard buying times. Buyer participation in order creation can greatly facilitate proactive freight consolidation.

Multivendor consolidation	Nonrelated firms can be coordinated by grouping the freight of the different shippers' together. The new initiative is jointly planning warehousing and order processing across different companies.

3. Negotiation

The key to effective negotiation is to seek **win-win agreements** wherein both the carriers and shippers share productivity gains. REMEMBER: the lowest possible cost for transportation may not be the lowest total cost of logistics. The traffic department must seek the lowest rate **consistent with service standards**!

4. Control

- **TRACING**

A procedure to locate lost or late shipments. Most large carriers maintain online tracing to aid shippers in locating a shipment. The tracing action must be initiated by the shipper's traffic department, but after that it is the carrier's responsibility to provide the desired information.

- **EXPEDITING**

The shipper notifying a carrier that it needs to have a specific shipment move through the carrier's system as quickly as possible and with no delays.

- **DRIVER HOURS ADMINISTRATION**

FMCSA: Federal Motor Carrier Safety Administration. **HOS**: hours of service.
HOS regulations are imposed by the government and they show how the government can influence transport. These regulations are important to ensure that the driver has enough off-duty time to rest while at the same time increasing daily driving time.

5. Auditing and claim administration

When transportation service is not performed as promised, shippers can make claims for restitution. Claims are typically classified as **loss and damage** or **overcharge/undercharge**.

Loss and damage	When a product is lost or damaged while in transit
Overcharge/undercharge	When the amount billed is different from that expected. This is usually solved by **freight bill auditing procedures**.

Two factors of claim administration are of primary importance:

- Detailed attention should be given to claim administration because recoveries are achieved only by aggressive audit programs.
- Large volumes of claims are an indication of carriers that are not performing well.

Auditing freight bills is an important responsibility of the traffic department. The purpose of auditing is to ensure freight bill accuracy. Transport rate complexity results in higher error probability.

Rreaudit	Determines proper charges prior to payment of a freight bill.
Postaudit	Makes the determination after the payment has been made.

The auditing can happen internally or externally. Bills with a larger recovery potential may best be audited internally, because they you get the full recovered amount without having to share it with the external auditing company.

Documentation

Products are typically being sold when being transported thus, a change in ownership occurs during the time the transport service is performed. The transaction must establish clear legal responsibilities of all parties involved.

→ PRIMARY PURPOSE OF DOCUMENTATION: **protect all involved parties!**

Bill of lading

Bill of lading	The basic document utilized in purchasing transport services. It serves as a receipt and documents products and quantities shipped.

The bill of lading is the basis for damage claims. The information contained on the BoL determines all responsibilities related to timing and ownership. It specifies terms and conditions of carrier liability and documents responsibilities for all possible causes of loss or damage except those defined as **force majeure** (circumstances beyond anyone's control).

Order-notified bill of lading	A credit instrument. It provides that delivery can not be made unless the original BoL is surrendered to the carrier.

The seller sends the order-notified BoL → bank or credit institution → customer pays → bank released the BoL → buyer presents BoL to common carrier → common carrier releases the goods

Export BoL	Permits a shipper to use export rates, which may be lower than domestic rates. This may reduce total costs when applied to domestic origin or destination line-haul transport.
Government BoL	Used when the product is owned by the government

Freight bill

Freight bill	Represents a carrier's method of charging for transportation services performed. Developed by using information form the BoL.

There are two types of freight bills:

- **A prepaid bill**: transport cost is paid by the shipper prior to performance.
- **A collect shipment**: shifts payment responsibility to the consignee.

Shipment manifest

Shipment manifest	Lists individual stops or consignees when multiple shipments are placed on a single vehicle. Each shipment requires a BoL.

The manifest lists 4 things: the stop, the BoL, weight and case count for each shipment.
It provides a single document that defines the overall contents of the load without requiring a review of all the individual BoLs.

Product pricing and transportation

A trend in price strategy is to **debundle** the price of products and materials so that services such as transportation, which were traditionally included in a delivered price, become separate and visible.

→ Pricing practices have a direct impact on the timing and stability of logistical operations.

FOB pricing

FOB	**= free on board** or **freight on board**

- **FOB origin**: the seller indicates the price at the point of origin and agrees to offer a shipment but assumes no further responsibilities. The buyer selects the mode of transportation, chooses a carrier, pays transportation charges and takes the risks of in-transit loss or damages.

- **FOB destination**: product ownership title does not pass to the buyer until the goods are delivered. The seller arranges the transportation and the charges are added to the sales invoice.

Delivered pricing

Delivered pricing	The seller established a price that includes transportation. The transportation cost is not specified as a separate item.

- **Single-zone delivered pricing**: buyers pay a single price regardless of where they are located. This is typically used when transportation costs are a relative small percentage of selling price.

- **Multiple-zone pricing**: established different prices for specific geographical areas.

- **Base-point pricing system**: in which the final delivered price is determined by the product's list price plus transportation cost from a designated base point, usually the manufacturing location.

Phantom freight	When a buyer pays transportation costs greater than those actually incurred to move the shipment.
Freight absorption	When a seller pays all or a portion of the actual transportation cost and does not recover the full expenditure from the buyer.

Pickup allowances

Pickup allowances	Buyers are given a reduction from the standard delivered price if they or a representative pick up shipments at the seller's location and perform transportation.

A buyer may also use a for-hire carrier or an integrated service provider to perform the pickup.

→ A **uniform pickup allowance** is often the price incentive offered to the customer closest to the shipping point.

Chapter 9: warehousing

Strategic warehousing

Initial warehouses provided a necessary bridge between production and marketing. Later the focus on warehousing shifted from passive storage to strategic inventory assortment. The term **distribution centre** became widely used to capture the dynamic development in traditional warehousing.

Strategic warehousing offered a way to reduce holding or dwell time of materials and parts. Warehousing became integral to just-in-time (**JIT**) and stockless production strategies.

- Strategically located warehouses are required.

- Important goal in warehousing: **maximize flexibility**
  → flexibility is an essential part of being able to respond to ever-changing customer demand in terms of product assortments, value-added services and the manner in which shipments are sequenced and presented.
  → information technology facilitates flexibility

- Strategic warehousing serves to satisfy requirements related to **local presence**.
  → Local warehouses can respond faster to customer needs than a more distant warehouse

Economic benefits

Economic benefits occur when overall logistic costs are reduced. Four basic economics benefits are:

1) Consolidation and break-bulk

Reduce transportation cost by using warehouse capability to increase the size of shipments.

- **Consolidation**: the warehouse receives inventory from a number of sources, that are combined into a large single shipment to a specific destination. Benefits: lowest possible freight rate, and timely and controlled delivery. Lower transportation costs per delivered unit.
- **Break-bulk**: receives a single large shipment and arranges delivery to multiple destinations.

2) Sorting

The benefit of sorting is to reconfigure freight as it is being transported from origin to destination.
There are three types of sorting:

- **Cross-docking**: combine inventory from multiple origins into a customized assortment to meet the needs of a specific customer. This requires precise on-time delivery from each manufacturer. As product is received and unloaded at the cross-dock, it is sorted by customer destination.
- **Mixing**: usually performed at an intermediate location between shipment origin and destination. Carloads or truckloads of products are shipped from origin to mixing facilities. These inbound shipments are planned to minimize inbound transportation cost. At the mixing warehouse shipments are unloaded and sorted into combination desired by each customer.
  → Net effect: reducing overall product storage, while achieving customer-specific assortments and minimizing transportation cost.
- **Assembly**: to support manufacturing operations. Products and components are assemble from a variety pf second-tier suppliers at an assembly facility located in close proximity to the manufacturing plant. Value-added services are used performed by an **integrated service provider (ISP)** to sort, sequence and deliver components when needed in manufacturing.

All three methods create a precise grouping of inventory at a precise time and location.

3) Seasonal storage

The benefit of seasonal storage is to accommodate either seasonal production or demand. Storage provides an inventory buffer, which allows production efficiencies within the constraints imposed by material sources and consumers.

4) Reverse logistics processing

Reverse logistics include activities to support:

- **Return management**: designed to facilitate the reverse flow of products that did not sell or to accommodate recalls
- **Remanufacturing and repair**: facilitates the reverse flow of products following their initial use for revitalization. Refurbished products can be reused or sold as appropriate.

- **Remarketers**: they use coordination and reverse flow to position and resell a product when the original user no longer needs it.

- **Recycling**: involves returning products following their useful life with the objective of decomposing it to its component materials so that they can be effectively reused.

- **Disposal**: when materials can't be effectively reused, it still may require reverse logistics for appropriate disposal.

Controlled inventory consists of hazardous materials and product recalls that have potential consumer health or environmental considerations. Less attention has traditionally focused on reclamation of regular or **non-controlled inventory**. The product involved in regular inventory reclamation is typically damaged, worn out or aged beyond the recommendable sell-by date.

In reverse logistics packages are often broken, and the product may not be packaged correctly. Return products typically require significant manual sortation and inspection to determine appropriate disposal.

Service benefits

It is a difficult assignment to quantify service on return-on-investment because it's hard to measure. Warehouses can improve service in three ways:

1) **Spot-stocking**

   Spot-stocking is used to support customer requirements. Manufacturers of highly seasonal products often spot-stock. Instead of maintaining inventory in a warehouse year-round, responsiveness in peak-selling periods can be enhanced through temporary inventory positioning in strategic markets. Following this concept, selected inventory is positioned or **spot-stocked** in a local market warehouse in anticipation of responding to customer needs during critical sales periods.

2) **Full-line stocking**

   The difference between full-line stocking and spot-stocking is the degree and duration of warehouse utilization. A firm using spot-stocking would temporarily warehouse a narrow product assortment in a large number of warehouses for a limited time. **Full-line stocking** is more often restricted to a few strategic locations and operates year-round.

   → Full-line stocking improves service by reducing the number of suppliers that customers must logically deal with.

3) **Value-added services**

   A value-added service is any work that creates a greater value for customers. They typically change the physical features or configuration of products so they are presented to customers in a unique or customized manner.

Warehouses can postpone final product configuration.
For example: **BRIGHT** → *cans (of vegetables etc.) without labels.* Holding inventory as bright means that the product is not committed to specific customer or carton configuration during initial manufacturing or processing.

Postponements provides two economic benefits:

→ risk is minimized because costumed packaging is not performed before customer orders
→ total inventory can be reduced by using inventory of the base product to aggregate demand across multiple customers' requirements.

Warehouse operations

A typical warehouse contains materials, parts and finished goods inventory. Warehouse operations consist of handling and storage. The objective is to receive inventory efficiently and store it as required. Assemble it to unique orders and then make customer shipments.

Handling

A first consideration is movement continuity and efficiency throughout the warehouse. Movement continuity means that it is better for an employee using handling equipment to perform longer moves than to undertake a number of short handlings to accomplish the same overall inventory move.

GENERAL RULE: longer warehouse handling movements are preferred

Ideally goods should be continuously moved once they are in motion, until they arrive at their final destination. Handling procedures should be designed to move cases grouped on pallets, slipsheets or containers. The overall objective is to eventually sort inbound shipment into unique customer assortments.

- **RECEIVING**
  The first handling activity is unloading. Unloading is performed using a combination of a lift truck, conveyors and manual processes. It is better when loads are received unitized because then you can rapidly unload and release inbound transportation equipment.

- **IN-STORAGE HANDLING**
  In-storage handling consists of inventory movements performed within the warehouse. The product is often moved within the facility for storage or order selection. Finally, when an order is processed it is necessary to select the required products and move them to the shipping area. These two types of in-storage handling are called **transfer** and **selection**.

  - **Transfer**: from the receive area → remote storage area → *order selection or picking area* (only for unit loads that need to be broken down) → the outbound shipment staging area

  - **Selection**: requires that materials, parts and products be grouped to facilitate order assembly. For each order, the combination of products must be selected and packaged to meet specific customer order requirements.

- **SHIPPING**
  Shipping consists of order verification and outbound transportation equipment loading. Warehouse shipping must accommodate relative low-volume movements of a mixture of products, thus reducing the potential for economies of scale. To facilitate this loading and subsequent unloading upon delivery, many customers request that suppliers provide mixed combinations of products within a trailer or on a pallet. Shipment content verification is typically required when a product changes ownership.

Storage

Slots	Specific locations

In planning warehouse layout, it is essential that products be assigned to **slots** on the basis of individual characteristics. The most important product variables to consider in a slotting plan are product velocity, weight and special storage requirements.

- **Product velocity**: high-volume products should be positioned in the warehouse to minimize movement distance. High velocity products should be placed near doors, primary aisles and at lower levels in storage racks → this minimizes warehouse handling and reduces the need for frequent lifting.

- **Product weight**: relatively heavy items should be assigned storage locations low to the ground to minimize lifting.

- **Storage requirements**: bulky or low-density products require cubic space. Smaller items may require storage shelves, bins or drawers.

ACTIVE STORAGE

Active storage	Storage for basic inventory replenishment. Active storage must provide sufficient inventory to meet the forecasted demand of the service area.

The active storage concept includes **flow-through** or **cross-dock distribution**, which uses warehouses for consolidation and assortment while maintaining minimal or no inventory in storage. The resulting need for reduced inventory favours flow-through and cross-docking techniques that emphasize on ***movement*** and de-emphasize on *storage*.

Flow through distribution is most appreciated for high-volume, fast-moving products where quantities are reasonably predictable.

EXTENDED STORAGE

Extended storage	When inventory is held for a longer time than required for normal replenishment of customer stocks.

Extended storage uses **handling processes and technologies** that focus on maximum space utilization with minimal need for quick access. Some products, such as seasonal items, require storage to await demand or to spread supply across time. *Product conditioning* sometimes requires extended storage, such as to ripen bananas.

Warehouses may also retain products for an extended basis when they are purchased on a speculative basis. For example, if a price increase for the item is expected you can purchase it now but then you'll have to keep it in stock longer. In this case the discount or savings have to be traded off against extended storage and inventory carrying cost.

Warehouse ownership arrangements

A private warehouse	Operated by the enterprise that owns the merchandise handled and stored in the facility.
A public warehouse	Operated as an independent business offering a range of for-hire services, such as storage, handling and transportation.
A contract warehouse	A customized extension of public warehousing, which combines the benefits of private and public warehousing. It is a long-term business arrangement that provides unique or tailored logistics services for a limited number of customers. The client and the warehouse provider typically share the risks associated with the operation.

Private

A private warehouse is operated by the firm owning the product, the building however may be owned or leased. Major benefits of private warehousing are:

- **Control**: management has the authority to prioritize activities. This should facilitate integration of warehouse operations with the balance of a firm's logistics operations.
- **Cost**: less costly than public warehousing because private facilities are not operated for a profit.
- **Flexibility:** operating policies, hours and procedures can be adjusted to meet specific customer and product requirements.
- **Intangible benefits**: a private warehouse with the firm's name on its sign may stimulate customer perceptions of responsiveness and stability. This perception may also provide a marketing image.

Despite the noted benefits the use of private warehouses is declining because of an increasing managerial interest in reducing capital invested in logistical assets.

Public

Almost any combination of services can be arranged on a for-hire basis for either short or long term. Public warehouses have traditionally been classified based on operational specialization such as:

- **General merchandise warehouses**: designed to handle package products like electronics, paper, food,…
- **Refrigerated warehouses**: offer frozen or cooler capacity designed to protect products requiring temperature control
- **Special commodity warehouses**: to handle bulk material or items requiring special handling
- **Bonded warehouses**: are licensed by the government to store prior to payment or taxes or import/export duties
- **Household goods or furniture warehouses**: handling and storing large, bulky items such as appliances and furniture

Public warehouses provide flexibility and shared services benefits. They have potential to offer operating and management expertise since warehousing in their core business. To may also achieve lower operating cost than private facilities. They typically do not require capital investment on the part of their customers either.

Public warehouses also have the potential to share scale economies since the combined requirements of users can be leveraged. This spreads fixed costs.

Contract

Long-term contractual relationships will usually result in lower total costs. In fact, many contract warehouse providers have extensive real estate investments. So a provider may be able to meet a customer's requirements in a combination of markets. Plus contract warehouse operations can provide benefits of expertise, flexibility, scalability and economies of scale by sharing management, labour, equipment and information resources across multiple clients.

Contact logistics firms are often called **Integrated service providers (ISPs)** and they are capable of performing a total logistics responsibility for an enterprise.

Network deployment

Full warehouse utilization throughout a year is rare. As a managerial guideline, a typical warehouse will be fully utilized between 75 and 85% of the time. So from 15 to 25% of the time, space needed to satisfy peak requirements will not be used.

→ in such situations a **deployment strategy** may be of use.

Developing a warehouse network strategy requires the answer to two questions:

- How many warehouses are required?
- Which warehouse ownership types should be used in specific markets?

Warehouse decisions

Site selection

The first task is to identify the **general area** and **he specific warehouse location**.

- **General area**: the broad geography where an active warehouse makes sense from a service, economic and strategic perspective
- **Specific warehouse location**: preferably central to a prerequisite number of retail store locations

The factors driving site selection are service availability and cost. Land cost is an important factor. The site must also offer adequate room for expansion. Necessary utilities must be available. The soil must be capable of supporting the structure. The site must be sufficiently high to afford proper water drainage.

Design

Design must consider product movement characteristics. Three factors to be determined are the number of floors to include in the facility, a cube utilization plan and a product flow.

IDEAL: a one-floor building so there is no need for usage of vertical handling devices. This helps to reduce bottlenecks.

GENERAL RULE: distribution warehouses should be designed as one-floor operations to facilitate handling. Warehouse design must maximize cubic utilization.

A product should be received at one end of the building, stored as necessary in the middle, and shipped from the other end. Straight-line product flow that facilitates velocity while minimizing congestion and redundant handling. (see figure 9.4. on page 565)

Product-mix analysis

The design and operation of a warehouse are both **dependent** on the product mix. Each product should be analysed in term of annual demand, weight, cube and packaging. It is also important to determine the total size, cube and weight of the average order to be processed through the warehouse.

Expansion

Future expansion should be considered during the initial planning phase. Building design should also accommodate future expansion.

Handling

The warehouse is viewed as a structure designed to facilitate efficient product flow. It is important to stress that the handling system must be selected early in the warehouse development process.

Layout

GENERAL: a larger pallet load = lower movement cost per pound or package over a given distance.

Analysis of product cases, stacking patterns and industry practices will determine the size of a pallet best suited to the operation. The second step in planning warehouse layout involves pallet positioning. The most common practise is **square placement**. Square placement means that the pallet is positioned perpendicular to the aisle. The placement of specific products in selected pallet locations is called **slotting**. Key to an efficient layout is a well-developed slotting plan!

Finally, the handling equipment must be integrated to finalize layout. The path and tempo of product flow depend upon the handling system.

- **Picking / selection area**: minimize the distance that order pickers must cover when assembling
- **Storage area**: when products are received they are palletized and moved to the storage area

Sizing

Each method begins with a projection of the total volume expected to move through the warehouse during a given period. The projection is used to estimate base and safety stocks for each product to be stocked in the warehouses. Failure to consider utilization rates can result in overbuilding.

Warehouse management systems (WMS)

Warehouse management systems (WMS)	Most firms depend on WMS to standardize work procedures and facilitate best practise.

One of the main uses of WMS is to coordinate order selection. There are two basic methods:

- **Discrete selection**: a specific customer's order is selected and prepared for shipment as the work assignment. Discrete selection is often used when order content and handling selection are critical.

- **Wave selection / batch selection**: can be designed and operationalized in multiple ways.
    - A wave can be coordinated by an area of the warehouse wherein all quantities of all products required to complete all customer orders are selected at one time.
    - Waves can also be planned around a specific shipment destination and/or carrier.

WMS also coordinates work procedures that are important for receiving and shipping. Work procedures are not restricted to floor personnel. Procedures must be established for administration and maintenance. Normally, there is limited interaction between buyers and warehouse personnel, although such communication is improving within integrated supply chain management organizations.

There are two problems:

- Buyers then to purchase in quantities that afford the best price with little attention given to pallet compatible quantities or available warehouse space.
    → ideally they should coordinate with warehouse personnel before commissioning large orders or introducing new products.
- The quantity of cases ordered. The goal is to purchase in pallet-multiple quantities.

Traditional activities are listed under **basic functionality**. Warehouses today must offer a broader range of services as they are frequently performing value-added services. They are also required to manage more inventory on a just-in-time basis.

Advanced functionality activities are: yard management, labour management, warehouse optimization, value-added services, planned cross-dock, returns management.

Value-added services	Refer to the coordination of warehouse activities to customize the product.

Yard management systems (YMS)

→ an important part of warehouse-related information technology. The YMS in essence couples the warehouse with inbound and outbound transportation equipment.

This coordination takes the form of arranging dock appointments for receiving ordered merchandise and transportation equipment for shipping outbound. From a performance perspective, the YMS is the **scheduler**.

It is essential to appropriately sequence inbound and outbound warehouse activity. It is also important to maintain an accurate accountability of what merchandise and transportation equipment is in the warehouse or factory yard.

YMS	The software that links and coordinates transportation (TMS) with the warehouse (WMS).

Accuracy and audits

WMS functionality requires verification of inventory accuracy, which is typically maintained by annual physical inventory counts or by counting specific portions of the inventory on a planned basis.

Cycle counting	The audit of selected inventory on a cyclic schedule.

Audits related to inventory accuracy are only one type of audits that is used to maintain and improve warehouse operating efficiency. Audits are also common to maintaining safety, assure compliance to security regulations, drive procedural improvement and facilitate work changes.

Security

PILFERAGE

It is necessary to protect against theft by employees and thieves as well as from riots and terrorist-related disturbances. Security begins at the fence. As standard procedure, only authorized personnel should be permitted into the facility and on surrounded grounds.

Inventory control and order processing systems help protect merchandise from being carried out of the warehouse unless accompanied by a computer release document. But not all pilferage occurs on an individual basis. There are also organized efforts between truck drivers and warehouse personnel.

A final concern is the increased incidence of hijacking over-the-road trailer loads from yards or while in transit.

DAMAGE

The most obvious form of product deterioration is damage from careless handling. The warehouse environment must be carefully controlled and measured to provide proper product protection. Of major concern is warehouse employee carelessness.
Another major form of deterioration is incompatibility of products stored or transported together.

Safety and maintenance

Accident prevention is a concern of warehouse management. A comprehensive safety program requires constant examination of work procedures and equipment to locate and take corrective action to eliminate unsafe conditions before accidents result.

Accidents occur when workers become careless or are exposed to mechanical or physical hazards. The floors of warehouses may cause accidents as well if they are not properly cleaned. Proper cleaning procedures can reduce the accident risk of such hazards. A preventive maintenance program is necessary for handling equipment.

Packaging and handling

Packaging and handling

Packaging is typically viewed as being either **consumer** (focused on marketing) or **industrial** (focused on logistics). The primary concern for logistic operations is industrial package design.

Individual products → grouped in cartons, bags, bins or barrels → grouped in containers / **master cartons**

Containerization / unitization	When master cartons are grouped into larger units
Unit load	When multiple master cartons are grouped together for handling the composite

The weight, cube and damage potential of the master carton determines transportation and handling requirements. Packaging and unit loads impact all supply chain movement and storage costs.

A prime objective in logistics is to design operations to handle a limited assortment of standardized master cartons. Master carton standardization facilitates materials handling and transportation.
The most important point is that **master carton standardization facilitates supply chain integration**!
When master cartons of more than one size are required, extreme care should be take to arrive at an assortment of compatible units.

Another packaging concern is the **degree of desired protection**. Package design and material must combine to achieve the desired level of protection without incurring the expense of overprotection. For package design there are two key considerations:

- the **cost** of absolute production will be prohibitive
- final package construction will be a blend of **protection** and **handling considerations**

A final logistics packaging consideration is the relationship between the master carton size, order quantity and retail display quantity. From a **handling perspective**, master cartons should be standardized and reasonably large to minimize the number of units handled.

However, for a **slow-moving product**, a master carton could contain an overstock of an item that sells only one unit per week but is packed in a case of 48 units. Finally, to minimize labour, retailers often place trays from master cartons on the retail shelf so that individual products do not have to be unloaded and placed on the shelves.

The determination of final package design requires a great deal of testing to assure that both marketing and logistics concerns are satisfied. To a large degree, care in design has been further encouraged by increased federal regulation regarding hazardous materials.

The four most common causes of product damage in a logistical system are:

- vibration
- impact
- puncture
- compression

Combinations of potential damage can be experienced whenever a package is being transported or handled. To obtain increased accuracy, computerized environmental simulations can be used to replicate typical conditions that a package will experience in the logistical system.

Packaging for handling efficiency

Handling efficiency is significantly influenced by packaging design, unitization and communication characterises.

Package design

Product packaging in standard configurations and order quantities facilitate logistical efficiency.
Cube minimization is most important for lightweight products such as assembled lawn furniture that **cubes out** a transport vehicle before weight limits are reached. On the other hand, heavy products like steel ball bearings or liquid in glass bottles typically **weigh out** transport vehicles before cube capacity is filled. When a vehicle or container weighs out, the firms ends up shipping empty cube space that can't be filled with products. Total weight can sometimes be reduced by product or package changes.

Cube and weight minimizations represent a special challenge for *mail order* and *e-commerce operations*. These operations tend to use standardized packaging for both purchasing and operating efficiencies. The result is often oversized packages that require excessive dunnage and increased shipping cost.

Unitization

Unitization or containerization	The process of grouping master cartons into one physical unit for materials handling or transport.

The concept includes all forms of product grouping, from taping two master cartons together to the use of specialized transportation equipment.

BASIC OBJECTIVE: increasing handling and transport efficiency

BENEFITS:
- unloading time and congestion at destination are minimized
- products shipped in unit load quantities facilitate handling
- inbound shipment verification is also simplified as receipts can be bar coded
- inventory can be positioned rapidly
- in-transit damage is reduced by unit load shipping

Rigid devices

Rigid devices	Provide an enclosure within which the master cartons or loose products are unitized.

The premise is that placing products inside a sealed container will both protect them and facilitate handling. **Returnable containers** have traditionally been used to distribute selected products. Most reusable containers are from steel or plastic.

→ Returnable containers are appropriate for ***integrated environments*** where there is reasonable container security between shipment origin and destination.

In a **returnable package system**, the parties must explicitly cooperate to maximize container usage. Otherwise containers may be lost, misplaced or used by other shippers.

Alternatively, **deposit systems** may be necessary in more free-flow supply chains, where members are linked by occasional or nonrepetitive transactions. Deposit systems are frequently used for beverages, bottles, kegs, pallets and steel drums.

BENEFITS OF RIGID DEVICES:
- improves overall material movement efficiency
- reduces damage in handling and transit
- reduces pilferage
- reduces protective packaging requirements
- provides greater protection from environmental elements

Flexible devices

Flexible devices	Do not protect a product by complete enclosure.

The most common types of nonrigid / flexible unitization is stacked master cartons on either **pallets** or **slipsheets**. A slipsheet, which is similar to a pallet in size and purpose, is a flat stocking surface generally made out of cardboard or plastic. Because they lie flat on the floor, special lift trucks are required to handle slipsheet unit loads.

ADVANTAGE of slipsheets:
- less costly than pallets
- they are insignificant from a weight and cube perspective

Most industry associations recommend that a standardized pallet or slipsheet size is used as a unit load platform. Generally, the larger a platform, the more efficient the associated handling. The final determination of size should be based upon load, compatibility with the handling and transport equipment used throughout the logistical system, and standardized industry practise.

With modern handling equipment, few restrictions are encountered in weight limitations. While pallets themselves are not flexible, the unit loads they contain are very flexible.

Basic pallet master carton stacking patterns are:

- block: used for cartons with equal width and length
- brick: load interlocking patterns can be used
- row: load interlocking patterns can be used
- pinwheel: load interlocking patterns can be used

load interlocking patterns: load stability is enhanced with interlocking.

The use of flexible unitization can increase damage potential if it is not properly contained during handling or transport. Standard methods for improving stability include rope tie, corner posts, steel strapping, taping and wrapping. → these methods tie the master cartons into the pallet stacking pattern.

Pallet exchange pools have been organized as a way to overcome traditional problems of return and exchange. High-quality pallets are expensive so warehouses routinely exchange low-quality pallets and keep the higher-quality ones.

Pallet pool	**Third-party suppliers** that maintain and lease high-quality pallets throughout the country for a variable fee per single cycle.

Communication

This function is becoming increasingly critical to provide content identification, tracking information, handling instructions and information essential for security.

The most obvious communication role is identifying package contents for all channel members: *manufacturers, product, count, Universal Product Code (**UPC**) and Electronic Product Code (**EPC**).* This may be communicated using a bar code or RFID.

The carton information is used to identify a product for receiving, order selection and shipment verification. **Visibility** is the major content identification consideration. Ease of package tracking is critical for effective internal operations. Positive control of all movement reduces product loss and pilferage. The information should note any special product handling consideration such as glass containers, temperature restrictions, stacking considerations or potential environmental concerns.

Handling

Advancements in handling technology and equipment offer the potential to substantially improve logistics productivity. They impact productivity by: influencing personnel, space and capital requirements.

Basic handling considerations

A fundamental difference exists in the handling of ***bulk materials*** vs. ***master cartons***.

- **Bulk handling**: situations wherein the product is handled without first being placed in master cartons. Specialized equipment is required for handling bulk materials. Bulk handling of fluids and gaseous materials is generally completed by using pipelines or conveyors.

Principle of handling:

- Equipment for handling and storage should be as standardized as possible
- When in motion, the system should be designed to provide maximum continuous product flow
- Investment should be in handling rather than stationary equipment
- Handling equipment should be utilized to the maximum extent possible
- In handling equipment selection the ratio of dead weight to payload should be minimized
- Whenever practical, gravity flow should be incorporated in system design

Handling systems can be classified as:

- **Mechanized:** a combination of labour and handling equipment, labour constitutes of a high percentage of overall costs.
- **Semiautomated**: a combination of mechanical and automated systems
- **Automated:** try to minimize labour by substituting equipment capital investment
- **Information-directed** : uses information technology to direct mechanized or automated handling equipment.

Mechanized systems

Employ a wide range of handling equipment. The types of equipment most commonly used are lift trucks, rider trucks, towlines, tractor-trailer devices, conveyors and carousels.

LIFT TRUCKS

Can move loads of master cartons but they are limited to handling unit loads. Many types of lift trucks are available, high-stacking trucks, palletless or clamp trucks, other variations for narrow aisle and side-loading operations.

The lift truck is not economical for long-distance horizontal movement. To overcome this limitation a great deal of research has focussed on ***driverless*** fork trucks. Conventional lift trucks are utilized in shipping and receiving operations and to place merchandise in high cube storage.

TOWLINES

Consist of either ***in-floor*** or ***overhead-mounted*** cable or drag devices. They are utilized to provide continuous power to four-wheel trailers. The main ADVANTAGE is the continuous movement. However, those handling devices have far less flexibility than lift trucks. The most common application for towlines is master carton order selection.

- In-floor installation is costly to modify and difficult to maintain.
- Overhead-mounted installation is more flexible, but the warehouse floor must be absolutely level. It also represents a potential danger to fork truck operations.

TRACTOR TRAILERS

Consists of a driver-guided power unit towing one or more four-wheel trailers. The tractor in combination with the trailer is used during order selection. The main ADVANTAGE is flexibility. But it is not as economical as the towline because each tow unit requires a driver.

CONVEYORS

Are used in shipping and receiving operations and serve as the basic handling device of a number of order selection systems. Conveyors are classified according to power, gravity, and roller or belt movement. Power configurations are less flexible.

CARROUSELS

Operates on a different concept than most other handling equipment's. Rather than requiring the order selector to go to the inventory storage location, the ***carousel moves inventory to the order selector***. The entire carousel rotates, moving the storage bin to a stationary product selection position.
→ typically used for selection of items to be packed for shipment

The rationale is to reduce order selection labour by reducing walking length and time. Systems such as **pick-to-light** are referred to as **paperless picking** because no paperwork exists to slow down employee efforts. A variation of the carousel system is ***movable racks***. Such racks move horizontally to eliminate the permanent aisle between the racks.

Semiautomated systems

AUTOMATED GUIDED VEHICLES (AGV)

An AGV system typically replaces mechanized tow tractors and trailers. The essential difference is that AGVs are ***automatically routed, positioned and activated without a driver***. The equipment relies on an optical, magnetic or wireless radio guidance system.

- Optical: directional lines are placed on the warehouse floor, the AGV is guided by a light beam focused on the guidepath.
- Magnetic: follow an energized wire installed within the floor.
- Wireless radio (wi-fi): guided by a high-frequency transmission

The primary ADVANTAGE of an AVG is direct labour reduction. Lower costs and increased flexibility have enhanced the application of AVGs for warehouse movements that are repetitive and frequent or occur in congested areas.

SORTATION

Typically used in combination with conveyors. As products are selected in the warehouse and placed on a conveyor for movement to the shipping dock , they often must be sorted into specific combinations for customer delivery.

Most sortation programs can be programmed to permit customized flow and decision logic to accommodate unique requirements. Automated sortation provides two major benefits:

- reduction in labour
- significant increase in speed and accuracy of order selection

ROBOTICS

The robot is a machine that can be programmed to perform one or more handling activities without the intervention of an attendant or driver. The primary use of robotics is materials handling in both manufacturing and warehouse operation environments.

Initially robotic applications were attractive as replacements for manual labour in highly repetitive situations. A primary benefit of robotics is their **sustainable performance accuracy**. Economic justification of robotics is typically driven by some combination of five factors:

1. Space limitations
2. Faster order to delivery cycle time requirements
3. Predictable and substantial throughput volume
4. High labour costs

5. Restrictive work environments such as frozen food or warehouse order selection

Other applications gaining popularity are inbound merchandise put-a-way and order selection in frozen food distribution centres.

The long-term potential for the application of robots throughout the supply chain is promising. Almost any handling task that involves repetitive movements is a candidate for either automation or robotic processing.

Of any particular interest to future supply chain operations is the growing combination of physicians and robots in medical surgery. In selected surgical procedures, experienced physicians provide guidance and make critical decisions during the operations. The robot, a precise machine, is instructed by the physician to follow a specific routine and complete in sequence precise surgical procedures.

Probotics	Expert knowledge combined with robotic capability.

LIVE RACKS

Storage rack design in which the product automatically flows to a selection position. The typical live rack contains roller conveyors and is constructed for loading from the rear. The rear of the rack is elevated higher than the front, causing a gravity flow towards the front.

This reduces the need to use lift trucks to transfer unit loads. A significant ADVANTAGE is the potential for automatic rotation of the product as a result of rear loading. Rear loading facilitates **FIFO inventory management**.

Automated systems

Emphasis is to automated high-rise storage and retrieval systems. The primary barriers are high capital investment and a low degree of flexibility.

POTENTIAL TO AUTOMATE

The appeal of automation is that is substitutes capital equipment for labour. It has the potential to operate faster and more accurately with less product damage than its mechanized counterpart.

Although information technology plays an important role in important part in all handling systems, it is essential in automated systems. Information technology controls the automated selection equipment and interfaces with the Warehouse Management System (**WMS**). A major disadvantage of automation is its dependency on proprietary information technology networks.

ORDER SELECTION

The general process begins with an automated order selection device preloaded with products. Merchandise is loaded from the rear and permitted to flow forward in the live rack on gravity conveyors until stopped by a rack door.

Upon receipt of an order, the warehouse control system generates sequenced instructions to trip the rack doors and allow merchandise to flow forward onto powered conveyors. The conveyors in turn transport merchandise to and order packaging area for individual products to be placed in shipment containers prior to transfer to the shipment staging area.

The handling of mast-moving products in master cartons, typical of cross-docking can be fully automated from the point of merchandise receipt to the placement in over-the-road trailers.

AUTOMATED STORAGE/RETRIEVAL

An automated unit-load handling system, or **automated storage and retrieval system (AS/AR)**, using high-rise storage is an increasingly popular form of automation. AS/Ars are particularly appropriate for items such as heavy boxes or those products in controlled environments such as bakeries or frozen food.

The four AS/AR components include storage racks, storage and retrieval equipment, input/output system, and control system.

Because humans are not an integral part of AS/RSs, these facilities are often referred to as **light-out facilities**. The typical **high-rise facility** consists of rows of storage racks. Most machines require guidance at the top and bottom to provide the vertical stability necessary for high-speed horizontal movement and vertical hoisting.

The initial function of the storage and retrieval equipment is to reach the desired storage location rapidly. A second function is to insert or remove merchandise form the rack. When the AS/RS operates with unit loads, the process is typically automated. However, the AS/RS often incorporates manual picking when the system selects cases or master cartons.

Transfer units may be **dedicated** or **nondedicated**.

Dedicated transfer car	Is always stationed at the end of the aisle in which the storage and retrieval equipment is working.
Nondedicated transfer car	Works a number of aisles and retrieval machines on a scheduled basis to achieve maximum equipment utilization.

The input/output system in high-rise storage is concerned with moving loads to and from receiving docks or production lines to the storage area. First, loads must be transported from receiving docks or production lines to the storage area. Second, within the immediate peripheral area of the racks, loads must be positioned for entry or exit.

For maxim input/output performance, the normal procedure requires different stations for transfer of inbound and outbound loads assigned to the same aisle. The pickup of discharge **(P/D)** stations are linked to the handling systems that transfer merchandise to and from the high-rise storage area.

AS/RSs seek to increase materials handling productivity by providing maximum storage density per square foot of floor space and to minimize direct labour required in handling. The highly controlled nature of an AR/RS achieves reliable pilferage-free and damage-free handling with extremely accurate control. However, AS/RSs are generally better as storage than as handling devices, thus reducing their appeal in situations where fast inventory turns are more important than inexpensive storage.

Information-Directed systems

Combines the control typical of automated handling with the flexibility of mechanized systems. Information-directed systems use mechanized handling controlled by information technology.

RF WIRELESS (Wi-Fi) and RFID

- RF wireless uses standard mechanized materials handling equipment coordinated by information technology to provide operator directions and control in real time. The basic use of Wi-Fi to instruct movement of lift trucks is expanded in an information-directed application to become a highly integrated materials handling system. The warehouse layout is often the same as any mechanized facility.

The difference is that all lift truck movements are directed and monitored by some combination of computer mounted on the lift track, handheld computer, or voice-activated communication. The information interchange is designed to achieve flexibility and better utilization.

ADVANTAGE: improve speed and flexibility of lift truck operations. It provides real-time communication to central data processing systems.

Decision support systems analyse all movement requirements to assign equipment in such a way that direct movement is maximized and deadhead movement is minimized. This process of assigning lift trucks to continuous assignments is called **task interleaving**.

Task internleaving	Lift trucks are assigned independent of traditional work areas to specific jobs or work areas that need resources such as receiving or shipping.

- RFID capabilities create the opportunity for two-way communication between specific products and lift truck operators.

Information-directed handling offers great potential because selected benefits of automation can be achieved without substantial capital investment. Information-directed systems increase productivity by tracking lift truck performance, thereby allowing compensation to be based on performance.
The main drawback of information-directed handling is accountability regarding work assignment.

The wide variety of work assignments increases the complexity and can decrease performance accountability.

Chaotic design	Builds on the flexibility of using RFID technology to allow warehouse to be stocked and operated to maximize inbound and outbound movement efficiency.

LIGHT DIRECTED (LDO)

Pick-to-light	Applications is a carousel system variation that is becoming increasingly common.

In this system, order selectors pick designated items directly into cartons or onto conveyors from **lighted** carousel locations or storage bins. A series of lights or a **light tree** in front of each pick location indicates the number of items to pick from each location.

Put-to-light	Where order selectors place products in lighted containers, each container assigned to a specific order or customer.

Special handling considerations

The primary mission of handling is to facilitate merchandise flow in an orderly and efficient manner from manufacturer to point of sale.

E-FULFILLMENT

Specific considerations that influence warehousing and handling in an e-fulfilment are: *order volume, small shipments and tracking*. First, an e-fulfilment must process a large number of very small orders. This means that it is difficult to achieve any substantial economies of scale for picking operations.
Second, facilities must generally deal with a wide range of products.
Firms electing to consolidate orders must have the capability to effectively receive and merge a large number of very small orders rapidly. Finally, many activities within the warehouse and with the carrier must be scanned and tracked so the customer always knows where it's product is.

In many cases, e-tailers are outsourcing fulfilment to integrated service providers (**ISPs**).

ENVIRONMENTAL CONCERNS

Attention has been directed to the impact of handling equipment such as lift trucks. Pollution of gas powered lift trucks is similar to that of automobile engines. There is also increasing interest regarding the handling and disposal of hazardous materials used.

REGULATORY ENVIRONMENT

The distribution warehouse is one of the most labour-intensive operations for most firms. It is also one of the most dangerous environments as numerous injuries occur annually.

PITOT: Power Industrial Truck Operator Training regulation requiring the training and revaluation of all lift truck drivers. Drivers failing the evaluation and those involved in accidents must undergo refresher training.

RETURNS PROCESSING

For a variety of reasons, merchandise may be recalled by or returned to a manufacturer. The only convenient method for processing reverse flows of merchandise is manual handling. Materials handling design should consider the cost and service impact of reverse logistics. Many firms are choosing to have returns processed by an integrated service provider to separate flows and reduce the chance for error of contamination.