INTRODUCTION TO OPERATIONS MANAGEMENT

WHAT IS OPERATIONS MANAGEMENT?

DEFINITIONS OF OPERATIONS MANAGEMENT (OM)?

Management of systems or processes that create goods and/or services.

"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, labour, and energy) into outputs (in the form of goods and/or services)."

- ***efficient*** *AND* ***effective:*** You need to produce products that are desired by the customers
- Achieve an economic match of supply and demand

SUPPLY CHAIN

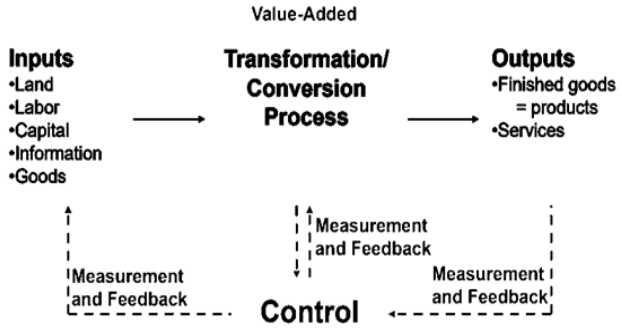
A sequence of activities and organizations involved in producing and delivering a good or service.

- Everything from raw material to customer

OM = MANAGING TRANSFORMATION PROCESSES

Managing of processes in which input are transformed into outputs.

The essence of the operations function is to add value during transformation process.



Feedback= measurements taken at various points in the transformation process

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

Value added: the difference between the cost of inputs and the value or price of outputs.

- The greater the value added the greater the effectiveness of these operations.
- Inputs can be transformed as well as transforme:
  - People can be input
  - People get transformed at the hairdresser
- Typical **material processors**:
  Mining and extraction, food production, automotive, assembly, machine construction, retail operations, warehousing and distribution, postal services, transport
- Typical **information processors**:
  Accountants, bank back offices, market research organization, financial analysts, news service, university research unit, archives, telecom company
- Typical **people processors**
  Hairdressers, hotels, hospitals, mass rapid transports, theatres, theme parks, dentists, schools

PRODUCTION OF GOODS VS. DELIVERY OF SERVICES

- **Goods** are physical items that include raw materials, parts, subassemblies, and final products
  - Tangible
- **Services** are activities that provide some combination of time, location, form, or psychological value. Generally implies an act.
  - Not always tangible
- Companies sell goods as well as services = product packages
  - Goods and services often occur jointly
  - Having the oil changed in your car is a service, but the oil that is delivered is a good
  - The goods-service combination is a continuum (It's difficult to say that something is just one of the two, products can be more a good than a service but they are still both)

Manufacturing matters

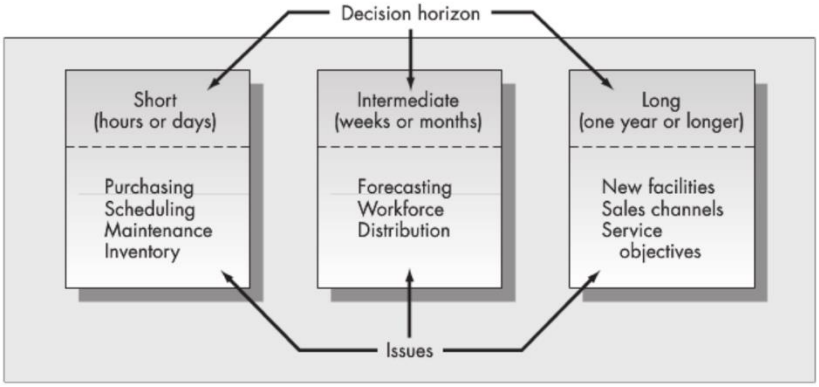
Shift from the manufacturing sector to the service sector towards a knowledge economy:

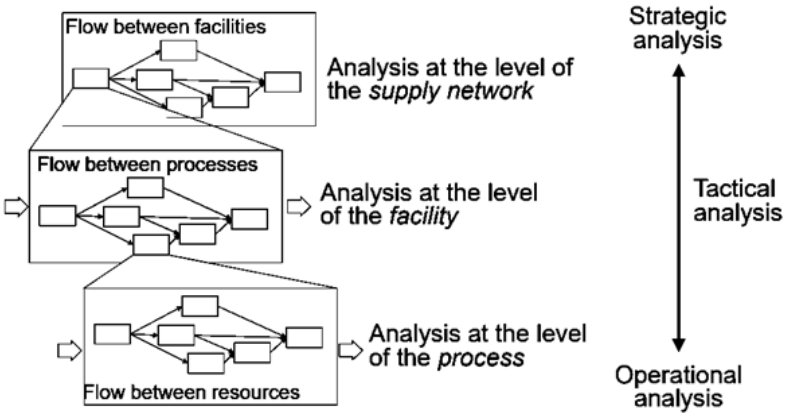
- Many services exist to support manufacturing
- Manufacturing and innovation
    - Manufacturing naturally leads to innovation
    - Return on innovations: after R&D

Decision horizon

OM ranges from strategic to tactical and operational levels.

- **Strategic issues:** Determining the size and location of manufacturing plants, deciding the structure of service or telecommunications networks, and designing technology supply chains.
    - Features of strategic issues: Long term, high impact, usually top management is involved
- **Tactical issues:** Plant layout and structure, project management methods, and equipment selection and replacement.
    - Features of tactical issues: Short term, lower management level makes their own decisions
    - How will I organize my plant ?
    - Not really a strategic issue because the elements within the plant can still change
- **Operational issues:** Production scheduling and control, inventory management, quality control and inspection, traffic and materials handling, and equipment maintenance policies.
    - Features of operational issues: Employees very low level can make these decisions.
    - Mapping of the worker shifts
- Strategic analysis can also be needed on process level
- Managing flows between processes
- Flow of goods
- Flow of funds
- Flow of information
    - Information needs to be shared to make the right decisions





Strategy and competition

- **Business strategy** sets the terms and goals for a company to follow = long term plan of action
    - Marketing strategy
    - Financial strategy
    - **Operations strategy:** The means by which the firm deploys its resources to achieve its competitive goals
      ↔ **Operations management** is concerned with implementing the operations strategy
    - Companies in the same business can have different strategies

SAMPLE OPERATIONS STRATEGIES

- Low price: to offer low prices I need low costs vb. Walmart, Colruyt, Aldi

↔ Delhaize: Wants to be close to the customer and make it a friendly environment

- Responsiveness: immediately delivering the product / service

A FRAMEWORK FOR OPERATIONS STRATEGY

Strategic dimensions (can be mixed)

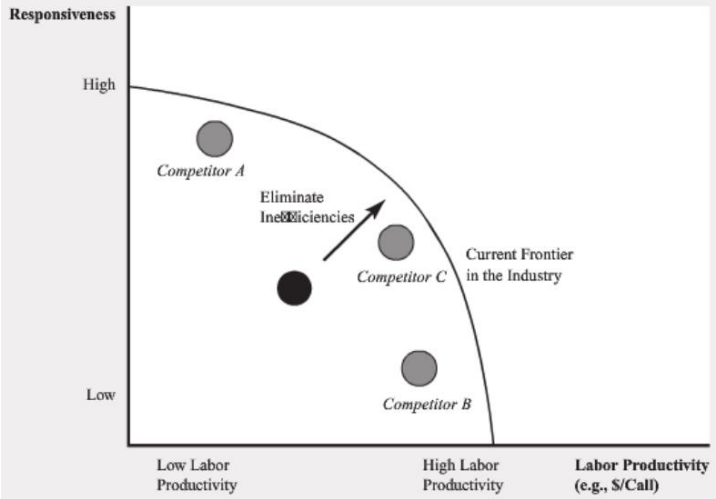
- Cost

- Product differentiation (both differentiation from competitors and differentiation within a firm)
- Quality
- Delivery speed
- Delivery reliability
- Flexibility

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

Competitiveness:

- How effectively an organization meets the wants and needs of customers relative to others that offer similar goods or services
- Organizations compete through some combination of their marketing and operations functions
    - What do customers want?
    - How can these customer needs best be satisfied?



OPERATIONS MANAGEMENT TOOLS

- Models And Quantitative Approaches
- Performance metrics
- Analysis of trade-offs

<u>use of OM tools to implement A strategy</u>

OM tools can be applied to ensure that resources are used as efficiently as possible

- The frontier (efficiency-curve) = the most efficient a company can be

OM tools can be used to make desirable trade-offs between competing objectives

- If a company is on the border:
    - It can shorten it's waiting time (more operator idle time) to get higher responsiveness
    - To get higher labour productivity it needs to make their waiting time longer so the operations are more fully utilized

OM tools can be used to redesign or restructure our operations so that we can improve performance along multiple dimensions simultaneously

- higher efficiency through redesigning their proces
- New frontier (efficiency-curve verder weg van de oorsprong)

STRATEGY FORMULATION

How to choose a strategy ?

- You need to take internal and external variables into account

Effective strategy formulation requires taking into account:

- Core competencies
- Environmental scanning

SWOT:

- Internal Factors
    - Strengths and Weaknesses
- External Factors
    - Opportunities and Threats

Successful strategy formulation also requires taking into account:

- Order qualifiers : Characteristics that customers perceive as minimum standards of 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

WHY SOME ORGANIZATIONS FAIL

- Neglecting operations strategy
- 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
- Neglecting investments in capital and human resources
- Failing to establish good internal communications and cooperation
- Failing to consider customer wants and needs

Performance measurement afb?

Balanced scorecard approach and key performance indicators KPIs

A top-down management system that organizations can use to clarify their vision and strategy and transform them into action

- Develop objectives
- Develop metrics and targets for each objective
- Develop initiatives to achieve objectives
- Identify links among the various perspectives
    - Finance
    - Customer: to achieve our vision, how will we appear to our customers?
    - Internal business processes
    - Learning and growth
- Monitor results

PERFORMANCE MEASUREMENT: KPI'S

Every company should have a performance scorecard, sometimes called '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:
    - People behave based on the way they are measured
    - What gets measured gets improved
    - It is hard to win a game without a scoreboard; it is hard to even know which game you are playing without a scoreboard

SCORE MEASURES

- **The Supply Chain Council (SCC)** has developed the Supply Chain Operations Reference (SCOR) model to describe, measure and evaluate supply chains. www.supply-chain.org
- As part of the model, five supply chain performance attributes and nine related measures were defined

Attribute	Measure
Reliability	- perfect order fulfillment
Responsiveness	- order fulfillment lead time
Flexibility	- upside flexibility (number of days required to achieve an unplanned sustainable 20% volume increase) - upside adaptability (sustainable volume increase that can be achieved in 30 days) - downside adaptability (reduction in quantities ordered sustainable at 30 days prior to delivery with no inventory or cost penalties)
Costs	- supply chain management costs - cost of goods sold
Asset management	- cash-to-cash cycle time - return of supply chain fixed assets

- These attributes can be used by various companies and fit within the balanced scorecard
- The point of these examples: you need to measure your performance in OM. If you don't follow up you will not have continuous improvement.

Productivity

How much output do you create provided you have a certain input ?

THE PRODUCTIVITY CHALLENGE

Productivity is the ratio of production output over production inputs

Productivity = Output/Input

- Input = labor, material, capital, energy,…
- Output = product orservice

Productivity = efficiency + effectiveness

- Efficiency = How well are the inputs used?
- Effectiveness = How well is the output made?
- Objective of productivity measurement: (reasons for measuring performance)
- To study the performance of a system over a period of time
- To compare the performance of different systems
- To compare the actual and planned productivity of a system

WHY PRODUCTIVITY MATTERS

- High productivity is linked to higher standards of living
- Higher productivity relative to the competition leads to competitive advantage in the marketplace Pricing and profit effects
- For an industry, high relative productivity makes it less likely it will be supplanted by foreign industry

Higher productivity means that more is produced with the same expenditure of resources.

- Why is productivity not that easy? Working more does not mean productivity improvement (e.g. shorter lunch breaks) it is not because you produce more that you are more productive

PRODUCTIVITY MEASUREMENT

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

- If an industry produces different types of output, a common unit of measurement is needed to obtain aggregate output
- The same is true for obtaining aggregate input when different input resources (land, labour, materials,…) are used

"Aggregation problem": difficult to sum labour , machines, …

To overcome this problem:

- Input and output can be expressed in monetary terms ('multifactor productivity')
- Partial productivities may be expressed

PARTIAL PRODUCTIVITY

The ratio of output over the input from a single factor

- $Material\ productivity = \frac{Total\ output}{Material\ input}$
- $Labor\ productivity = \frac{Total\ output}{Man\ hours}$
- $Capital\ productivity = \frac{Total\ output}{Cost\ of\ capital}$
- $Material\ productivity = \frac{Total\ output}{Energy\ consumption}$

The type of partial productivity used depends on the nature of the enterprise:

- For capital intensive industries: capital productivity
- For industries with costly material resources: material productivity

FORECASTING

INTRODUCTION TO FORECASTING

Forecast

What is forecasting?

A statement about the future value of a variable of interest.

- Primary function is to predict the future.
- Why are we interested? Affects the decisions we make today.
    - Examples: We make forecasts about such things as weather, demand, and resource availability
- Forecast demand for products and services
- Forecast availability of manpower
- Forecast inventory and material needs daily
- Reference to a specific time horizon
- Short-term forecasts
- Long-term forecasts
- New products, new equipment,.
- Things that require a long lead time to develop, construct or implement
- All users need to agree on the same forecast (accounting, finance,..)
- Yield management
- Plan a system
- Plan the use of a system
- Really bad forecasting: Ryanair
- Company did not think their employees wanted to take their vacation days
- Pilots wanted to take vacation
- Promised a bonus if they did not take them
- Being on time was a strategy for them
- A lot of flights were cancelled

Characteristics of forecasts

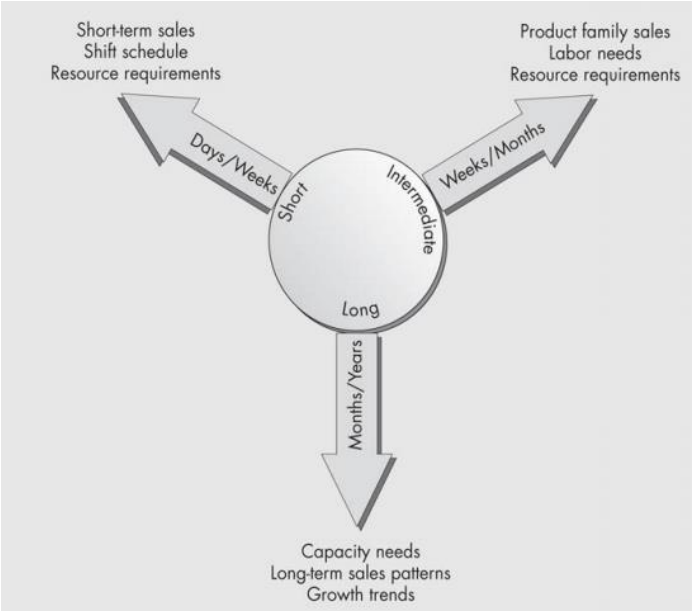
- Forecasting techniques assume that some underlying causal system that existed in the past will continue to exist in the future .
- Forecasts are not perfect. They are usually wrong!
    - Because random variation is always present
    - There will always be some residual error, even if all other factors have been accounted for
- A good forecast is more than a single number
- Expected level of demand the level of demand may be a function of some structural variation such as trend or seasonal variation
- Accuracy related to the potential size of forecast error
- Aggregate forecasts (forecasts for groups of items) are usually more accurate than those for individual items
    - Beter A, B en C samen schatten dan alleen
- Forecasting errors among items in a group usually have cancelling effects
- Accuracy erodes as we go further into the future.

- Forecasts should not be used to the exclusion of known information.
- Forecast accuracy decreases as the time period covered by the forecast increases.

ELEMENTS OF A GOOD FORECAST

The forecast

- Should be timely: Time is needed to respond to information contained in a forecast.
- Should be accurate and the degree of accuracy should be stated
- Should be reliable, it should work consistently.
- Should be expressed in meaningful units.
- Should be in writing, guarantee that the same information is used.
- Technique should be simple to understand and use
- The users should understand the limits of the forecasts and in which circumstances it is used.
- Should be cost-effective
    - Een heel moeilijk maar correcter model is vaak duurder dan een minder correct model, rekening houden met de kosten



FORECAST HORIZONS IN OPERATION PLANNING

FORECAST USES

Plan **the system**

- Generally involves <u>long-range plans</u> related to:
- Types of products and services to offer
- Facility and equipment levels
- Facility location

Plan the **use of the system**

- Generally involves <u>short- and medium-range</u> plans related to:
- Inventory management
- Workforce levels
- Purchasing
- Production
- Budgeting
- Scheduling

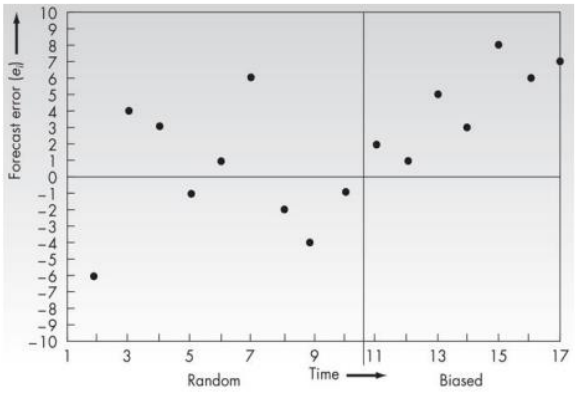
STEPS IN THE FORECASTING PROCESS

1. Determine the purpose of the forecast
    - How will it be used and when will it be needed? This steps provides an indication of how detailed your forecasts needs
2. Establish a time horizon
3. Obtain, clean, and analyse appropriate data
4. Select a forecasting technique
5. Make the forecast
6. Monitor the forecast errors

EVALUATION OF FORECASTS

Forecast accuracy and control

- Minimize forecast errors
- Allowances should be made for forecast errors
- It is important to provide an indication of the extent to which the forecast might deviate from the value of the variable that actually occurs
- Forecast errors should be monitored
- Error = Actual – Forecast
- If errors fall beyond acceptable bounds, corrective action may be necessary
- e = A - F
- Forecast errors influence decisions in two ways
- Making a choice between various forecasting alternatives.
- Evaluating the success or failure of a forecasting technique.



1. Forecasts should be unbiased: E (error (t)) = 0
    a. Plot forecast errors over time to detect a bias →
    - Biased model (right): All the errors are positive
    - Expected error is positive
    - Always overestimating
    - Good forecasting model: error = 0
2. Different measures of forecast accuracy

Forecast accuracy metrics

- MAD: Mean absolute deviation
- MSD: Mean squared error
- MAPE: Mean absolute percentage error

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

MAD weights all errors evenly

when forecasts errors are normally distributed (as generally assumed): $\sigma_e \approx 1.25 \times MAD$

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

MSE weights errors according to their squared values

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

MAPE weights errors according to relative error

Forecast error calculation

Period	Actual (A)	Forecast (F)	(A-F) Error	|Error|	Error²	[|Error|/Actual]x100
1	107	110	-3	3	9	2.80%
2	125	121	4	4	16	3.20%
3	115	112	3	3	9	2.61%
4	118	120	-2	2	4	1.69%
5	108	109	1	1	1	0.93%
			Sum	13	39	11.23%
				$n = 5$	$n-1 = 4$	$n = 5$
				MAD	MSE	MAPE
				= 2.6	= 9.75	= 2.25%

FORECASTING APPROACHES

Qualitative Forecasting

- Qualitative techniques permit the inclusion of soft information such as
    - Human factors
    - Personal opinions
    - Hunches
- These factors are difficult, or impossible, to quantify
    - Geen historische gegevens nodig

Quantitative Forecasting

- These techniques rely on hard data
- Quantitative techniques involve either the projection of historical data or the development of associative methods that attempt to use causal variables to make a forecast

QUALITATIVE FORECASTING METHODS

Qualitative forecasts

Forecasts that use subjective inputs such as opinions from consumer surveys, sales staff, managers, executives, and experts

Executive opinions

- A small group of upper-level managers may meet and collectively develop a forecast
- Long-range planning and new product development

Sales force 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.
- Influenced by recent experience, after a few low sales periods people tend to be more pessimistic.
- Forecasts are used to establish a sales quota, there will be a conflict of interest because it is to the salespersons advantage to estimate low sales
    - Low sales estimate so they sell more than that and get a bonus for selling more.

Consumer surveys

- Since consumers ultimately determine demand, it makes sense to solicit input from the
- Consumer surveys typically represent a sample of consumer opinions

Other approaches

- Managers may solicit opinions from other managers or staff people or outside experts to help with developing a forecast.
- **The Delphi method** is an iterative process in which managers and staff complete a series of questionnaires to achieve a consensus forecast.
    - Long-term single time forecasts with little hard information available.
    - Responses are kept anonymous to encourage honest answers and reduce the risk of one person's opinion prevailing.
    - Verschillende groepen zullen verschillende gemiddelden aangeven ?
    - Iedere expert moet alleen zijn gemiddelde verkoopcijfers doorgeven bv
    - Alle experts komen samen en bespreken hun cijfers
    - Ze zijn gelijk of er is geen consensus
    - Hoge en lage cijfers laten uitleggen waarom ze zo hoog of laag hebben geschat
    - ...

TIME-SERIES FORECASTS

Forecasts that project patterns identified in recent time-series observations

- Time-series - a time-ordered sequence of observations taken at <u>regular time intervals</u>
- Assume that <u>future values</u> of the time-series can <u>be estimated from past values</u> of the time-series.
- Analysis of time-series data requires the analyst to identify the underlying behaviour of the series.
    - Plotting the data and visually examining the plot and looking for patterns.

<u>Time series behaviours (patterns):</u>

Trend: A long-term upward or downward movement in data

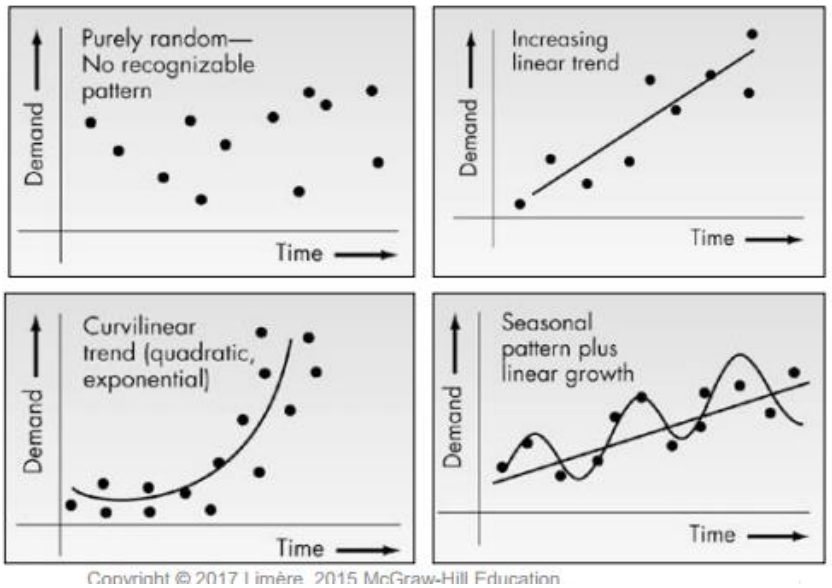
- Population shifts
- Changing income

Seasonality: Short-term, fairly regular variations related to the calendar or time of day

- Restaurants, service call centres, and theatres all experience seasonal demand
- Loopt samen met tijd
- Weekly, daily, monthly,..

Cycles: Wavelike variations lasting more than one year (not linked to timing such as seasonality)

- These are often related to a variety of economic, political, or even agricultural conditions



- Timing isn't important, goes up and down and isn't linked to the time

Irregular variations: Due to unusual circumstances that do not reflect typical behaviour

- Labour strike

- Weather event
- Major changes in products or services
- Should be identified and removed from the data

Random variation: Residual variation that remains after all other behaviours have been accounted for

1. Naive Forecast

Uses a single previous value of a time series as the basis for a forecast

- The forecast for a time period is equal to the previous time period's value

Can be used with

- **A stable time series:** the forecast for a time period is equal to the previous time period's value
  - Last week demand was 20, so this week demand will also be 20
- **Seasonal variations**: Look back what happened one season ago
  - What was the demand last thanksgiving season, this year it will be the same…
- Trend
- Doesn't do anything complex
  - Not able to provide accurate information
  - Accuracy is acceptable tho
  - Cheap and easy 7
- Traces data with a lag of one period
  - Doesn't smooth at all

2. Techniques for Averaging

To predict the future you use the past average. Remove white noise (random variations), smooth the data.

These techniques work best when a series tends to vary about an average (stationary series)

- Averaging techniques smooth variations in the data
  - Averages tend to be less variable than the original data
  - This is good because a lot of these variations are because of random variability rather than a true change in the series
  - Responding to change is a great cost
  - It is desirable to avoid reacting to minor variations
  - Larger variations are seen as real changes
- They can handle step changes or gradual changes in the level of a series
- Techniques
  3. Moving average
  4. Weighted moving average
  5. Exponential smoothing

MOVING AVERAGE

Technique that averages a number of the most recent actual values in generating a forecast.

- Moves as new data becomes available.

Moving average lags behind a trend. The number of data points included in the average determines the model's sensitivity.

$$F_t = \text{MA}_n = \frac{\sum_{i=1}^{n} A_{t-i}}{n} = \frac{A_{t-n} + \ldots + A_{t-2} + A_{t-1}}{n}$$

where

F_t = Forecast for time period t

MA_n = n period moving average

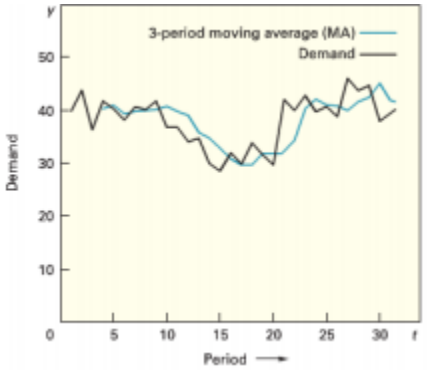
A_{t-i} = Actual value in period $t-i$

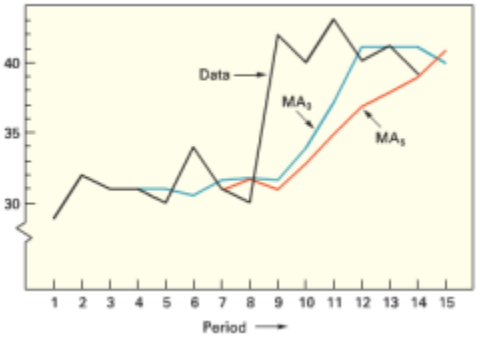
n = Number of periods in the moving average

- Fewer data points used - more responsive
- More data points used-- less responsive
- Drops and rises are predicted later

MONTH	Demand	Month	Demand
January	89	July	223
February	57	August	286
March	144	September	212
April	221	October	275
May	177	November	188
June	280	December	312

3 month MA: (oct+nov+dec)/3=258.33
6 month MA: (jul+aug+…+dec)/6=249.33
12 month MA: (Jan+feb+…+dec)/12=205.33



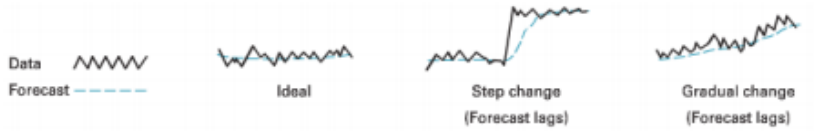


A moving average forecast tends to smooth and lag changes in the data.

The more periods in a moving average, greater the average will lag changes in the data.

Advantages of moving average method

- Easily understood
- Easily computed
- Provides stable forecasts



Disadvantages of moving average method

- Require saving lots of past date points: At least N periods used in the moving average compute
- Lags behind trend
- Ignores complex relationship data
- All data are weight the same (1/N)

WEIGHTED MOVING AVERAGE

The most recent values in a time series are given more weight in computing a forecast, otherwise similar to moving average.

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

where

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.

- The choice of weights, Wt , is somewhat arbitrary and involves some trial and error
- Weighting factors must add to one
    - If the sum is over 1, you are overestimating
    - Sum lower than 1: Underestimating
- More reflective of the most recent occurrences

EXPONENTIAL SMOOTHING

A weighted averaging method that is based on the previous forecast plus a percentage of the forecast error.

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

- $0 < \alpha \leq 1$ is the smoothing constant

- α = Percentage of the error
- Actual – Previous forecast = Forecast error

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

where

F_t = Forecast for period t

F_{t-1} = Forecast for the previous period

α = Smoothing constant

A_{t-1} = Actual demand or sales from the previous period

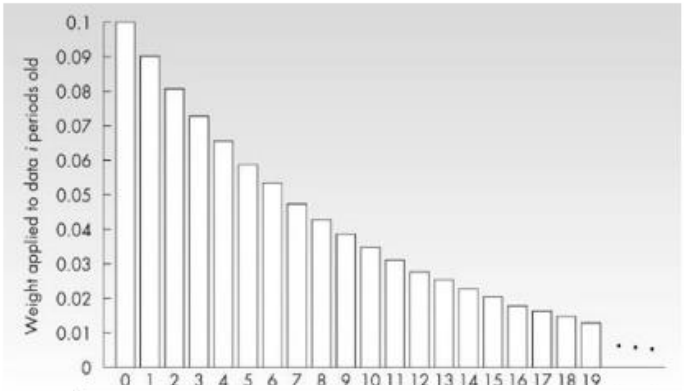
Smoothing:

- If Ft is too high, e_t is positive, and the adjustment is to decrease the forecast
- If Ft is too low, e_t is negative, and the adjustment is to increase the forecast
- Appropriate for data that varies around an average or has a gradual change

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

Infinite expansion for F_{t+1}: $F_{t+1} = \alpha A_t + (1-\alpha)(\alpha)A_{t-1} + (1-\alpha)^2(\alpha)A_{t-2} + \cdots = \sum_{i=0}^{\infty} \alpha(1-\alpha)^i A_{t-i}$

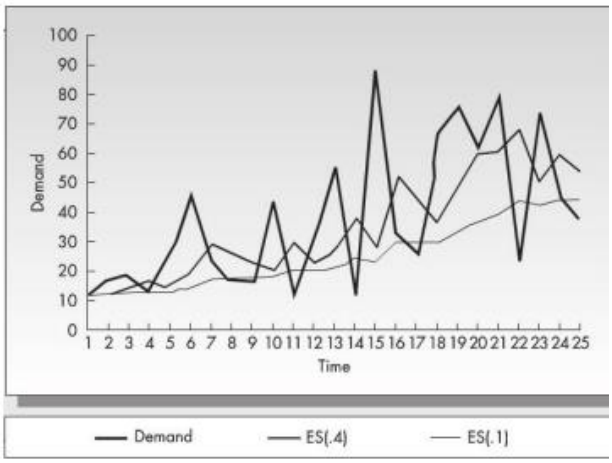
- A set of exponentially declining weights applied to past data
- It is easy to show that the sum of the weights $\sum_{t=0}^{\infty} \alpha(1-\alpha)^t = 1$
- Houdt alle historische gegevens bij en geeft deze ook gewichten
- Hoe ouder de gegevens, hoe lager de gewichten



EFFECT OF α VALUE ON THE FORECAST

The quickness of forecast adjustment to error is determined by the smoothing constant (α):

- The closer the value to zero, the slower the forecast will be to adjust to forecast errors (= greater smoothing)
- The closer α to 1, the greater the responsiveness and the less the smoothing



The goal is to select an a smoothing constant that balances the benefits of smoothing random variations

- Small values of means that 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 mean that the forecast will more closely track the actual time series (quick reaction to changes)
- For production applications, stable demand forecasts are desired
- Therefore, a small α is recommended around 0.1 to 0.2
    - You decide which alpha is best for your company
    - Most companies chose a low α
    - Example:

COMPARISON OF MA (MOVING AVERAGES) AND ES (EXPONENTIAL SMOOTHING)

Similarities

- Both methods are appropriate for stationary series
- Both methods lag behind a trend
- Both methods depend on a single parameter
- For both methods multiple-step-ahead and one-step-ahead forecasts are identical Extended notation: (Ft+1 = Ft,t+1) = $Ft,t+\tau$

Differences

- ES carries all past history (forever!)
- MA eliminates "bad" data after N periods
- MA requires all N past data points to compute new forecast estimate while ES only requires last forecast and last observation of 'demand' to continue

3. Trend-based methods

Analysis of a trend involves developing an equation that will suitably describe trend (assuming that trend is present in the data). A simple data plot can reveal the existence and nature of a trend. (exclusively linear trends because they are fairly common)

LINEAR TREND EQUATION

$$F_t = a + bt$$

where

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 $t = 0$

ESTIMATING SLOPE AND INTERCEPT

Slope and intercept can be estimated from historical data

$$b = \frac{n\sum ty - \sum t \sum y}{n\sum t^2 - \left(\sum t\right)^2}$$

$$a = \frac{\sum y - b\sum t}{n} \text{ or } \bar{y} - b\bar{t}$$

where

n = Number of periods

y = Value of the time series

TREND-ADJUSTED EXPONENTIAL SMOOTHING

Double exponential smoothing or **Holt's method**: Variation of exponential smoothing used when a time series exhibits a linear trend.

- Appropriate for data that shows a trend
- predict steepness and level

The trend adjusted forecast consists of two components–

- Smoothed error
- Trend factor
- we only look one step ahead

One-step-ahead forecast

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

where

S_t = Previous forecast plus smoothed error

T_t = Current trend estimate

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

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

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

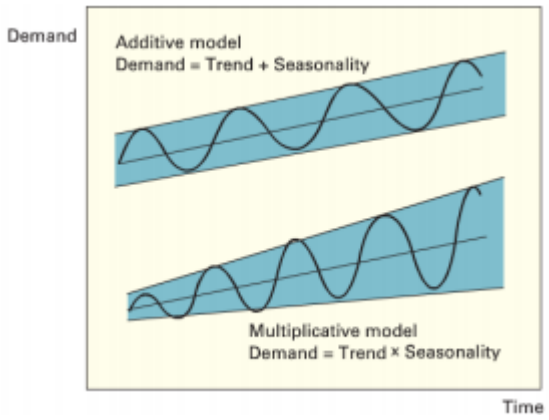
- α and β are smoothing constants
  - Chosen through trial and error
- Trend-adjusted exponential smoothing has the ability to respond to changes in trend
- We begin with an estimate of the intercept and slope at the start (e.g., by using linear regression)
- Easier to calculate new forecasts by redefining the smoothing equations than regression analysis
- The smoothing constants may be the same, but often more stability is given to the slope estimate : (usually $\beta \leq \alpha$)

4. Methods for seasonal series

TECHNIQUES FOR SEASONALITY

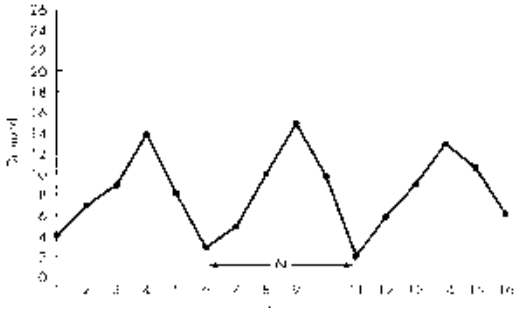
Seasonality: Regularly repeating movements in series values that can be tied to recurring events

- Expressed in terms of the amount that actual values deviate from the average value of a series
- Models of seasonality
  - **Additive**: Seasonality is **expressed as a quantity** that gets added to or subtracted from the time-series average in order to incorporate seasonality.
    - Series tends to vary around an average = seasonality expressed in terms of that average (or moving average)
  - **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
    - Trend is present
    - More used because it tends to be more representative of actual experience



SEASONAL RELATIVES

Seasonal relatives C_t $(seasonal\ indexes)$: 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

$$\Sigma c_t = N$$

c_t = 1.25 implies a 'demand' 25% higher than the baseline

c_t = 0.75 implies 25% lower than the baseline

Using seasonal relatives

- To **depersonalize data**
  - Done in order to get a clearer picture of the non-seasonal (e.g., trend) components of the data series
    - Remove seasonality from data in order to discern other patterns or lack of patterns in series
  - Divide each data point by its seasonal relative
- To **incorporate seasonality** in a forecast
  1. Obtain trend estimates for desired periods using a trend equation
  2. Add seasonality by multiplying these trend estimates by the corresponding seasonal relative

COMPUTING SEASONAL RELATIVES USING THE SIMPLE AVERAGE METHOD

- Alternative way to compute seasonal relatives:
  - Each seasonal relative is the average for that season divided by the average of all seasons.
- Quick and dirty method of estimating seasonal factors
- Compute the sample mean of the entire data set (should be at least several cycles of data)

Season	Week 1	Week 2	Week 3	Average	SA Index
Tues	67	60	64	63.667	63.667/71.571 = 0.8896
Wed	75	73	76	74.667	74.667/71.571 = 1.0432
Thurs	82	85	87	84.667	84.667/71.571 = 1.1830
Fri	98	99	96	97.667	97.667/71.571 = 1.3646
Sat	90	86	88	88.000	88.000/71.571 = 1.2295
Sun	36	40	44	40.000	40.000/71.571 = 0.5589
Mon	55	52	50	52.333	52.333/71.571 = 0.7312
				71.571	

- Divide each observation by the sample mean: this gives a factor for each observation
- Average the factors for like seasons

→ The resulting n numbers will exactly add to N and correspond to the N seasonal factors

Period	Season	Actual	MA	Center	Index
1	Tues	67			
2	Wed	75			
3	Thur	82			
4	Fri	98		71.857143	1.3638171
5	Sat	90		70.857143	1.2701613
6	Sun	36		70.571429	0.5101215
7	Mon	55	71.857143	71	0.7746479
8	Tues	60	70.857143	71.142857	0.8433735
9	Wed	73	70.571429	70.571429	1.034413
10	Thur	85	71	71.142857	1.1947791
11	Fri	99	71.142857	70.714286	1.4
12	Sat	86	70.571429	71.285714	1.2064128
13	Sun	40	71.142857	71.714286	0.5577689
14	Mon	52	70.714286	72	0.7222222
15	Tues	64	71.285714	71.571429	0.8942116
16	Wed	76	71.714286	71.857143	1.0576541
17	Thur	87	72	72.428571	1.2011834
18	Fri	96	71.571429	72.142857	1.3306931
19	Sat	88	71.857143		
20	Sun	44	72.428571		
21	Mon	50	72.142857		

After normalizing:

- $c_{mon} = 0.7486$
- $c_{tue} = 0.8690$
- $c_{wed} = 1.0463$
- $c_{thu} = 1.1983$
- $c_{fri} = 1.3652$
- $c_{sat} = 1.2386$
- $c_{sun} = 0.5341$

AVERAGES

0.7484 for Monday
0.8688 for Tuesday
1.0460 for Wednesday
1.1980 for Thursday
1.3648 for Friday
1.2383 for Saturday
0.5339 for Sunday

Slightly more complex, but can be used to predict a seasonal series with or without a trend

→ an example with N=7

- De factor varieert rond 1
- Geen trend enkel seizoen-verandering (effect)
- Als er een trend is, dan is dit een slechte methode want je vergelijkt met het globale gemiddelde ?

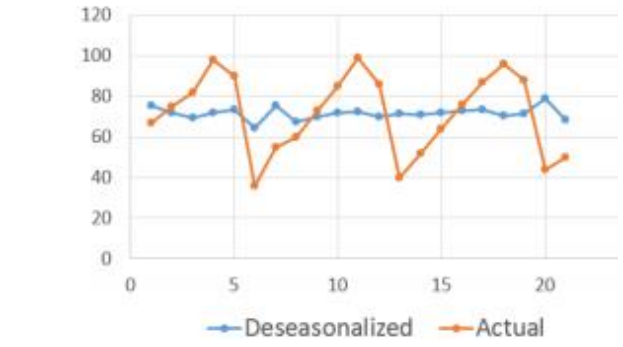
- N: number of periods in one cycle
- After 7 days my pattern repeats itself
  - Moving averages over 7 periods
  - 71.85: vergae of the first 7 days etc
  - Moving because you move the time each time you calculate the average
- Next step is to centre the data ?
- Period 4 is the middle period ?
  - Demand for Friday is 98
  - Average was lower

- 36% higher than expected = Ct value for Friday
- Average value: 1.37 + 1.4 + 1.33 = 1.3
- Sum of the seasonal relatives isn't 7
  - (in tegenstelling tot het voorbeeld hierboven omdat je het hier 'beweegt' en bij het bovenste voorbeeld niet) Fout in slides die in de les gegeven werden (blauw is verbetering …)

FORECASTING FOR SEASONAL SERIES

- To remove seasonality from a series, simply divide each observation in the series 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 depersonalized series, one then multiplies that forecast by the appropriate seasonal factor to obtain a forecast for the original series.

Period	Season	Actual	Deseasonalized
1	Tues	67	75
2	Wed	75	72
3	Thur	82	69
4	Fri	98	72
5	Sat	90	73
6	Sun	36	64
7	Mon	55	75
8	Tues	60	67
9	Wed	73	70
10	Thur	85	72
11	Fri	99	73
12	Sat	86	70
13	Sun	40	72
14	Mon	52	71
15	Tues	64	72
16	Wed	76	73
17	Thur	87	74
18	Fri	96	70
19	Sat	88	72
20	Sun	44	79
21	Mon	50	68



BUT 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 • Is there a method to smooth this seasonalized technique?
- Yes, 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 (causal models) are based on 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

- Home values may be related to such factors as home and property size, location, number of bedrooms, and number of bathrooms

Simple linear regression

(geen lineaire regressie kunnen bereken, het is geen statistiek les)

Regression - a technique for fitting a line to a set of data points

- The simplest form of regression that involves a linear relationship between two variables
- The object of 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

$y_c = a + bx$

where

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

$$b = \frac{n(\sum xy) - (\sum x)(\sum y)}{n(\sum x^2) - (\sum x)^2}$$

$$a = \frac{\sum y - b\sum x}{n} \text{ or } \bar{y} - b\bar{x}$$

where

n = Number of paired observations

FORECASTING IN PRACTICE

MONITORING THE FORECAST

Tracking **forecast errors** and analysing them can provide useful insight into whether forecasts are performing satisfactorily

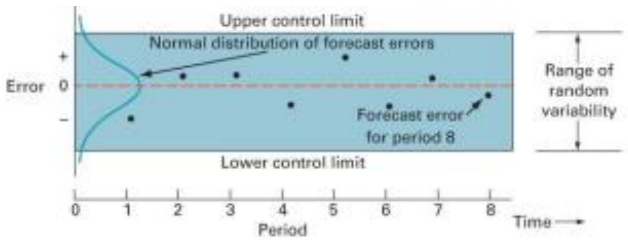
- Sources of forecast errors:
  - The model may be inadequate due to:
    1. Omission of an important variable
    2. A change or shift in the variable the model cannot handle
    3. The appearance of a new variable
  - Irregular variations may have occurred
  - Random variation
- **Control charts** are useful for identifying the presence of non-random error in forecasts
  - Non-random variations need to be investigated
  - Control charts: Visual tool for monitoring forecast errors
- **Tracking signals** can be used to detect forecast bias
  - To detect any bias in errors over time
  - Detect a tendency for a sequence of errors to be positive or negative
  - A value of zero is ideal
  - If a value outside the acceptable range occur, that would be taken as a single that there is a bias in the forecast

$$Tracking\ signal_t = \frac{\sum(Actual_t - Forecast_t}{MAD_t}$$

CONTROL CHART CONSTRUCTION

Control charts: Visual tool for monitoring forecast errors

- Errors are plotted in the control chart in the order they occur
- The centre line represents an error of zero
- Upper and lower limits (above and below centre line) represent the range of acceptable variations for the errors
- Errors are judged in control when
  - All errors are within control limit.
  - No pattern is present



1. Compute the MSE.
2. Estimate of standard deviation of the distribution of errors
   $s = \sqrt{\text{MSE}}$
3. UCL : $0 + z\sqrt{\text{MSE}}$
4. LCL : $0 - z\sqrt{\text{MSE}}$

where z = Number of standard deviations from the mean

How to construct a control chart:

- Compute MSE and take its square root
- Control charts are based on the assumption that when errors are random, they will be distributed according to normal distribution around a mean of zero
- Z = number of standard deviations from the mean

Choosing a forecasting technique

Factors to consider

- Cost
- Accuracy
- Availability of historical data
- Availability of forecasting software
- Time needed to gather and analyse data and prepare a forecast
- Forecast horizon
    - Short-range: Moving average and exponential smoothing
    - Long-term: Trend and Delphi-method

Operation strategy

The better forecasts are, the more able organizations will be to take advantage of future opportunities and reduce potential risks

- A worthwhile strategy is to work to improve short-term forecasts
- Accurate up-to-date information can have a significant effect on forecast accuracy:
    - Prices
    - Demand
    - Other important variables
- Reduce the time horizon forecasts have to cover
- Sharing forecasts or demand data through the supply chain can improve forecast quality

STRATEGIC CAPACITY PLANNING

INTRODUCTION

Capacity: The upper limit or ceiling on the load that an operating unit can handle

- Capacity needs include
    - Equipment
    - Space
    - Employee skills

Strategic capacity planning Goal:

- To achieve a match between the long-term supply capabilities of an organization and the predicted level of long-term demand
    - Overcapacity⇢ operating costs that are too high
        - Costs can't be recovered
        - Lower demand
    - Under-capacity ⇢ strained resources and possible loss of customer
        - Lost sales: Demand is higher than production, sales you could have made if your supply was higher.

Key Questions:

- What kind of capacity is needed?
    - Product design and process design
- How much is needed to match demand?
    - Different capacity each period ?
- When is it needed?

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 DECISIONS ARE STRATEGIC

1. Impact the ability of the organization to meet future demands
    - Limits rate of possible output
2. Affect operating costs
    - Fixed costs through decisions of capacity
    - These fixed cost continue to exist even if you lower your production
    - Possible loss of market share due to loss of customer whom go to the competitors
3. Are a major determinant of initial cost
4. Often involve long-term commitment of resources
    - Difficult to modify without increasing costs
5. Can affect competitiveness
    - Create an entry barrier for other companies
    - Delivery speed can be effected

6. Affect the ease of management
7. Have become more important and complex due to globalization
    - Worldwide demand and supply makes capacity decisions more difficult
    - Customers can get their products everywhere and you can get your supplies everywhere
8. Need to be planned for in advance due to their consumption of financial and other resources

DEFINING AND MEASURING CAPACITY

Capacity is often referred to as ' upper limit on the rate of output'

- Measure capacity in units that do not require updating
    - Units per time
    - Units per output
        - Availability of inputs:
        - Example: Hospital: Capacity isn't measured in output but in number of beds
    - Why is measuring capacity in dollars problematic:
        - Changes in price require updating of the measure

Two useful definitions of capacity

- **Design capacity**: best case in optimal condition
    - The maximum output rate or service capacity an operation, process, or facility is designed for
- **Effective capacity**
    - Design capacity minus allowances such as personal time and maintenance

Measuring system effectiveness

Actual output

- The rate of output actually achieved
- It cannot exceed effective capacity

$$\text{Efficiency} = \frac{\text{actual output}}{\text{effective capacity}} \qquad \text{Utilization} = \frac{\text{actual output}}{\text{design capacity}}$$

- Both measured as percentages
- You need to calculate both when making a decision
    - Effective capacity low compared to design capacity
        - High efficiency does not indicate effective use of resources in those cases.
        - Key to improve capacity utilization is to increase effective capacity by correcting problems, maintaining equipment in operating conditions, training employees, and fully utilizing bottleneck equipment.
        - Increasing utilization depends on being able to increase effective capacity, and this requires a knowledge of what is constraining effective capacity.
        - Benefits op high utilization are realized only in instances where there is demand for output
            - Exes output results in additional variable costs and also generates cost of having to carry output inventory.

DETERMINANTS OF EFFECTIVE CAPACITY

Many decisions about system design have an impact on capacity.

- Facilities
  - Size and provision for expansion
  - Transportation cost, distance to market
  - Lay out of the work area
- Product and service factors
  - The more uniform the output, the more opportunities for standardisation of methods and materials
- Process factors
  - Quantity capability
  - Quality
  - How effective is your production process
- Human factors
  - Motivated and always present
  - Training, skills and experience
- Policy factors
  - Overtime is regulated
  - Number of shifts per day
- Operational factors
  - Scheduling
  - Inventory stocking decisions
- Supply chain factors
  - Major capacity changes ?
    - What impact will the changes have on suppliers, warehousing, transportation and distribution?
    - Will the supply chain be able to handle increase in capacity?
  - Supply chain needs to be able to deal with your supply
- External factors
  - Minimum quality
  - Pollution standards

STRATEGY FORMULATION

Strategies are typically based on assumptions and predictions about:

- Long-term demand patterns
- Technological change
- Competitor behaviour

These typically involve

1) The growth rate and variability demand.
2) The cost of building and operating facilities of various size.
3) The rate and direction of technological innovation.
4) The likely behaviour of competitors.
5) Availability of capital and other inputs.

Different capacity strategies:

1. **Leading capacity strategy:**
   - Build capacity in anticipation of future demand increases
   - If capacity increases involves a long lead time
2. **Following strategy :**
   1. Build capacity when demand exceeds current capacity.
3. **Tracking strategy :**
   - Similar to the following strategy, but adds capacity in relatively small increments to keep pace with increasing demand.

Capacity Cushion

- Extra capacity used to offset demand uncertainty
- Capacity cushion strategy
- Organizations that have greater demand uncertainty typically have greater capacity cushion
- Organizations that have standard products and services generally have smaller capacity cushion

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

Capacity planning decisions involve both long-term and short-term considerations.

- Long-term considerations relate to overall level of capacity, such as facility size
- Short-term considerations relate to probable variations in capacity requirements created by such things as seasonal, random, and irregular fluctuations in demand.

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

SERVICE CAPACITY PLANNING

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

- The need to be near customers
  - Convenience

- The inability to store services
    - Cannot store services for later consumption
- The degree of demand volatility
    - Volume and timing of demand
    - Time required to service individual customers

To match supply with demand, three types of buffers may be used:

1) Inventory (e.g., bread) – Remark: not possible for services
2) Time (e.g., patients waiting in the hospital)
3) Capacity (e.g., guests in a luxury hotel)

DEMAND MANAGEMENT STRATEGIES

Strategies used to offset capacity limitations and that are intended to achieve a closer match between supply and demand

- Pricing
- Promotions
    - Als je hoog en laag periodes hebt
    - Bij lage verkopen kunnen je promoties voeren zodat de verkoop weer stijgt
    - Niet te hoge verkopen op 1 periode waaraan je niet kan voldoen
    - Seasonal demand afvlakken
- Discounts
- Other tactics to shift demand from peak periods into slow periods

IN-HOUSE OR OUTSOURCE?

Once capacity requirements are determined, the organization must decide whether to produce a good or service itself or outsource.

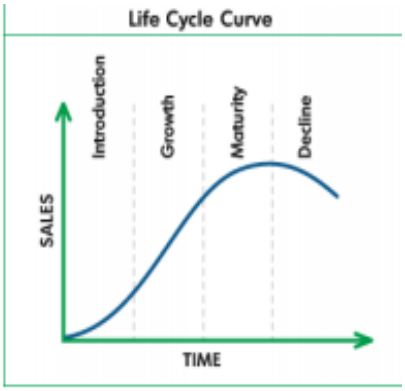
Factors to consider:

- Available capacity
    - Cost to make it are relatively small compared with those required to buy the product
    - Needed Time and equipment
    - Outsourcing can increase
- Expertise
    - If you lack expertise, buying might be a reasonable alternative
- Quality considerations
    - Firms that specialize can usually offer higher quality
- The nature of demand
    - High and steady: Produce it yourself
    - Fluctuating or small orders are better handled by specialists
- Cost
- Risks
    - Loss of direct control
    - Liability

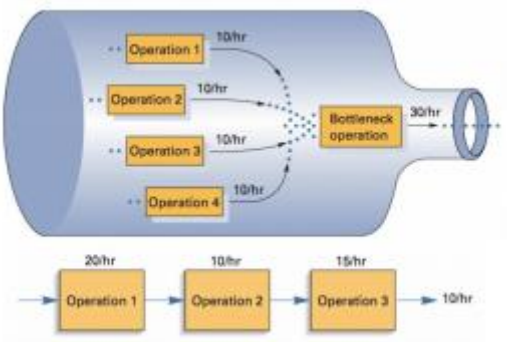
DEVELOPING CAPACITY ALTERNATIVES

Things that can be done to enhance capacity management:

1. <u>Design flexibility into systems</u>
   - The long-term nature of many capacity decisions and the risk inherent in long-term forecasts suggests potential benefits from designing flexible systems.
   - Removing an existing structure is more expensive than provision for future expansion.
   - Modification to existing structure can be minimized
     - Expanding of a restaurant
   - Location, lay-out of equipment, equipment selection.. are other considerations in flexible design

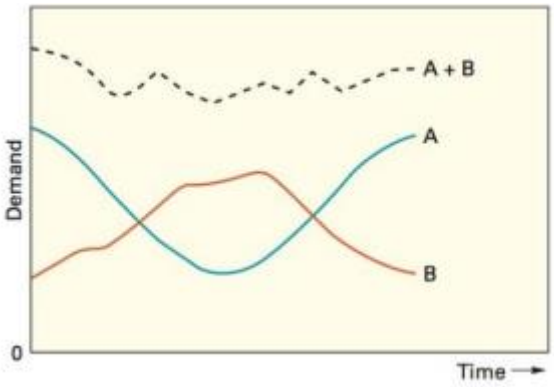


2. <u>Take stage of life cycle into account</u>
   - Capacity requirements are often closely linked to the stage of the life cycle that the products or services are in
   - **Introduction phase**: Overall market may experience rapid growth
     - Growth means increasing market share
     - Increase in volume will follow and thus increase in profit
     - Increase in capacity and investments needs to happen too!
     - Competitors might increase their volume too which means that the risk overcapacity increases too.
   - **Maturity phase**: Stable market share.
     - Increase profitability by reducing costs
   - **Decline phase**: underutilization due to declining demand $
     - Selling excess capacity
     - Introducing new products or services
3. <u>Take a "big-picture" approach to capacity changes</u>
   - When developing capacity alternatives, it's important to consider how parts of the system interrelate.
   - Capacity changes affect an organisation's supply chain
     - Suppliers need time to adjust their capacity
   - The risk of not taking a big)picture approach is that the system is unbalanced (bottle-neck operation)
     - Bottleneck operation: An operation in a sequence of operations whose capacity is lower than that of the other operations.
       - Limiting the system capacity
       - The capacity of the system is reduced to the capacity of the bottleneck



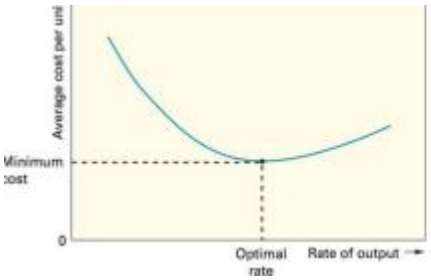
4. <u>Prepare to deal with capacity "chunks</u>
   - Capacity increases are often acquired in fairly large chunks rather than smooth increments, making it difficult to achieve a match between desired capacity and feasible capacity.
   - Example: One machines produces 40 units, two machines produce 80 but the desired capacity is 55
5. <u>Attempt to smooth capacity requirements</u>
   - Unevenness in capacity requirements can create certain problems
   - Systems tend to alternate between underutilization and overutilization

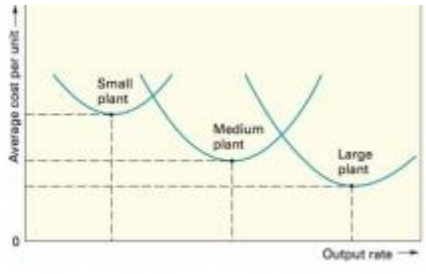
- Seasonal varieties:
  - Predictable
  - Ex. During bad weather, public transportation ridership tends to increase
  - Complementary demand patterns:: Patterns that tend to offset each other (A and B have complementary demand patterns)
  - The products use the same resources but at different times, so the overall capacity requirements remain fairly stable and inventory levels are minimized
  - EX demand for snow and water skis



- Random variaties
- Higher demand isn't always met with higher capacity through expanding of operations size (they increase fixed costs and you lose flexibility)
  - Overtime
  - Subcontract some of the work

6. <u>Identify the optimal operating level as a function of facility size</u>
   - Productions usually have an optimal level of operations in terms of Input or output.
   - Cost per unit is at its lowest for that production
   - **Economies of Scale** If output rate is less than the optimal level, increasing the output rate results in decreasing average per unit costs
   - **Diseconomies of Scale** If the output rate is more than the optimal level, increasing the output rate results in increasing average per unit costs.
   - Change in capacity gets you on a different curve





7. <u>Choose a strategy if expansion is involved</u>
   - Incremental expansion or signal step expansion ?
   - Leading of following strategy ?

(Dis)economies of scale

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

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

CONSTRAINT MANAGEMENT

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

Categories

- Market: Insufficient demand
- Resource: Too little of one or more resources
- Material: Too little of one or more materials
- Financial: Insufficient funds
- Knowledge or competency:
- Policy
- Supplier

Resolving Constraint Issues

1. Identify the most pressing constraint
2. Change the 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

EVALUATING ALTERNATIVES

Alternatives should be evaluated from varying perspectives

<u>Economic</u>

- Is it economically feasible?
- How much will it cost?
- How soon can we have it?
- What will operating and maintenance costs be?
- What will its useful life be?
- Will it be compatible with present personnel and present operations?

Non-economic

- Possible negative public opinion
    - Disrupt lives etc.

Technique for evaluating alternatives

- Cost-volume analysis

And other techniques

- Financial analysis
- Decision theory
- Waiting-line analysis
- Simulation

Cost-volume analysis

Focuses on the relationship between cost, revenue, and volume of output. Estimates income of an organisation under different operating conditions. Used to compare capacity alternatives.

- **Fixed Costs (FC):** Tend to remain constant regardless of output volume
- **Variable Costs (VC)** vary directly with volume of output

  VC = Quantity(Q) x variable cost per unit (v) = Q*v

- **Total Cost**

  TC = FC + VC
- **Total Revenue (TR)**

  TR = revenue per unit (R) x Q = R*Q

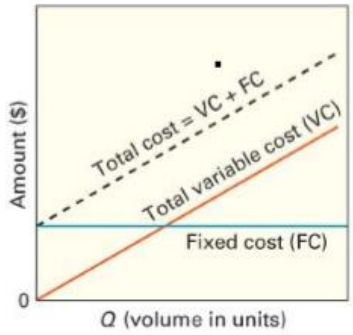
Break-Even Point (BEP)

- The volume of output at which total cost and total revenue are equal

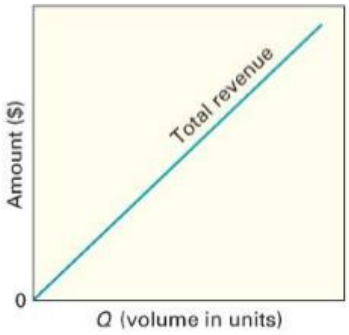
  Profit (P) = TR – TC = R x Q – (FC +v x Q)

  = Q(R – v) – FC

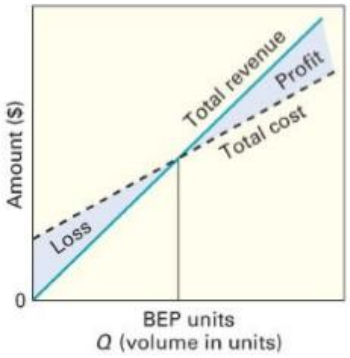
$$Q_{BEP} = \frac{FC}{R - v}$$



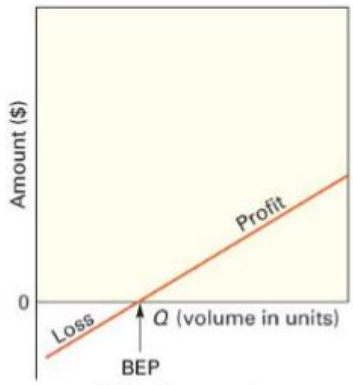
A. Fixed, variable, and total costs



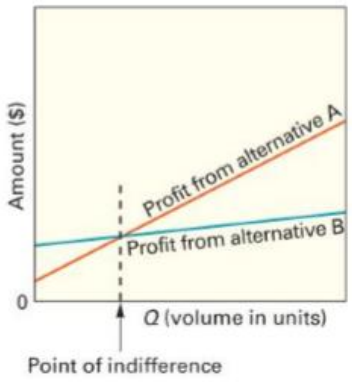
B. Total revenue increases linearly with output



C. Profit = TR – TC



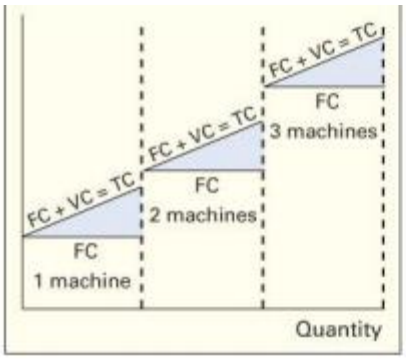
D. Profit versus loss



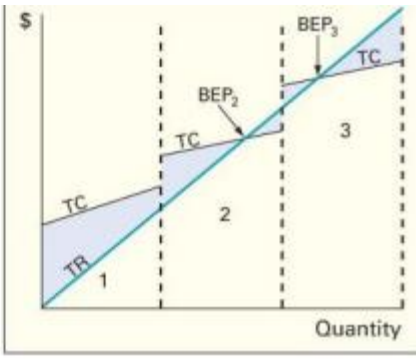
E. Point of indifference for two alternatives

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 <u>of multiple break-even quantities.</u>
- Buy more machines of you want to produce more



A. Step fixed costs and variable costs



B. Multiple break-even points

Cost-volume analysis assumptions

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

1. One product is involved
2. Everything produced can be sold
3. The variable cost per unit is the same regardless of volume
4. Fixed costs do not change with volume changes, or they are step changes
5. The revenue per unit is the same regardless of volume
6. Revenue per unit exceeds variable cost per unit

Important to verify that the assumptions on which the technique is based are reasonably satisfied for a particular situation.

OPERATIONS STRATEGY

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 be agile
  - Responsive to market changes
  - It reduces the organization's dependence on forecast accuracy and reliability
  - Many organizations utilize capacity cushions to achieve flexibility
    - Blocking market entry for new competitors, producing at lowers costs
- Efficiency and utilization improvement
  - Streamlining operations and reducing waste
- Bottleneck management is one way by which organizations can enhance their effective capacities
- Capacity expansion strategies are important organizational considerations
  - Expand-early strategy: Before demand capitalizes
    - Achieve economies of scale, expand market share,..
  - Wait-and-see strategy: Expand demand after it materializes
    - Lower chance of oversupply
- Capacity contraction is sometimes necessary
  - Capacity disposal strategies become important under these conditions

PROCESS SELECTION AND FACILITY LAYOUT

PROCESS SELECTION

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

It has major implications for:

- Capacity planning
- Layout of facilities
- Equipment
- Design of work system

Process selection occurs as a matter of course when new products or services are being planned or periodically due to technological changes.

How an organisation approaches process selection is determined by the organization's process strategy.

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 choice is demand driven. Two key questions in process selection:

1. How much variety will the process need to be able to handle?
2. How much volume will the process need to be able to handle?

The answer to these questions will serve as a guide to selecting an appropriate process . Volume and variety are inversely related: a higher level of one means a lower level of the other.

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

- Flexibility is directly related to variety
    - The lower the variety the lower the needed flexibility

Process types

	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

Some situations are not ongoing but instead are of limited duration.

Project: A project is used for work that is non-routine, with a unique set of objectives to be accomplished in a limited time frame.

- e.g. consulting project, building a bridge, making a movie
- Job variety, process flexibility and unit costs are highest for Job Shop, and get progressively lower moving down..

Sustainable production of goods and services

There is increasing pressure for organizations to operate sustainable production processes

According to the Lowell Center for Sustainable Production:

> "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; and, socially and creatively rewarding for all working people"

- Reduce waste and by products
- Eliminate chemical substances or physical agents that present a hazard to human health.
- …

Process and information technology

Process and Information technology can have a major impact on costs, productivity and competitiveness:

- **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
- Technological innovation (discovery and development) vs technology (implementation of scientific knowledge)

Automation

Automation: Machinery that has sensing and control devices that enable it to operate automatically

- **Fixed automation**: High-cost, specialized equipment for a fixed sequence of operations. High volume production of the exact same product.
- **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. Produces a fairly wide variety of low-volume products in small batches.
    - Ex. Robots, can be reprogrammed if necessary
- **Flexible automation**: Evolved from programmable 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.

FACILITY LAYOUT

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

Facilities layout decisions arise when:

- Designing new facilities
- Re-designing existing facilities
    - Inefficient operations

Facilitate layout problems

• Hospitals • Warehouses	• Workstations • Banks	• Shopping centres	• Schools • Offices	• Industrial plants	• Airports

Layout design objectives

Basic Objective

- Facilitate a smooth flow of work, material, and information through the system.

Supporting objectives

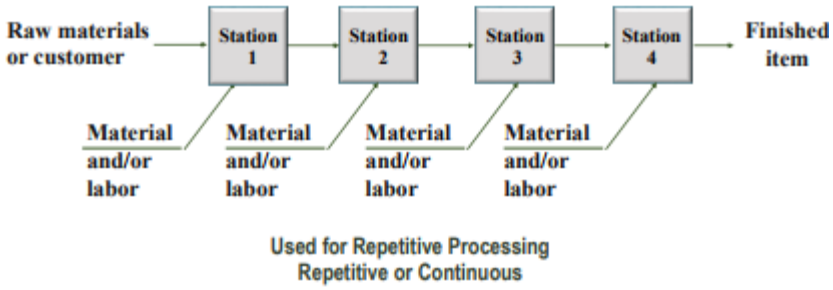
1. Facilitate product or service quality
2. Use workers and space efficiently
3. Avoid bottlenecks
4. Minimize material handling costs
5. Eliminate unnecessary movement of workers or material
6. Minimize production time or customer service time
7. Design for safety

Basic layout types

- Product layouts: Most conductive to repetitive processing.
- Process layouts: Intermittent processing.
- Fixed-Position layout: Used when projects require layouts.
- Hybrid layouts

Repetitive processing: Product layouts

Layout that uses standardized processing operations to achieve **smooth, rapid, high-volume flow**.



- An assembly line: Standardized layout arranged according to fixed sequence of assembly tasks.
- Highly standardized goods
- If one section fails, all fails

Resources are organized in order to create optimal flow from one operation to the next

- When there is a limited range of high quantity products
- Highly capital intensive
- Not work intensive: reduced material handling costs
- Little work-in-process inventory and short lead times
- Dedicated production lines for very high runners
- Production lines per product family for B-products
- Low flexibility but high efficiency

Advantages

- 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

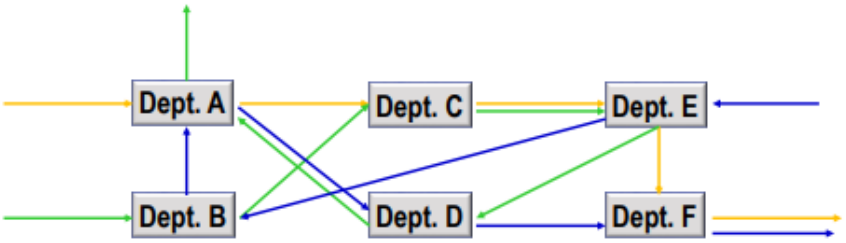
Disadvantages

- 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

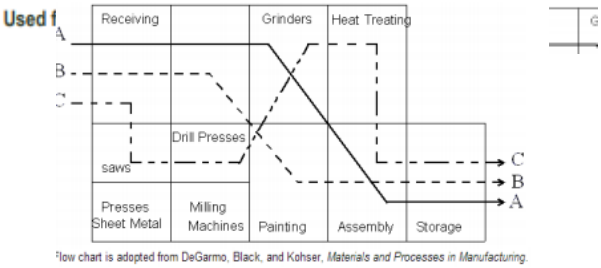
Non-Repetitive processing: **Process layouts**

Layouts that can handle varied processing requirements

The variety of jobs that are processed requires frequent adjustment of equipment.



- When there are many low quantity products
- General-purpose machinery
- Reduced capital intensity
- Work intensive: higher material handling costs
- Production in batches: work-in-process inventory and lead times increase
- High flexibility but low efficiency
- Common in service environments.



Advantages

- 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

Disadvantages

- 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 layouts

Layout in which the product or project remains stationary, and workers, materials, and equipment are moved as needed.

- This due to the nature of the product: weight, size,..

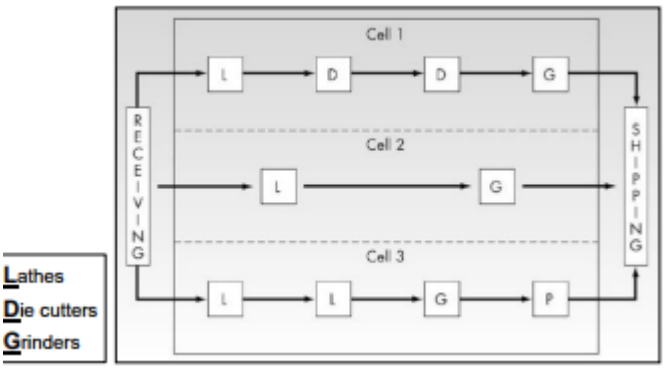
Hybrid layouts

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

- Hospitals
- Supermarket
- Shipyards

Some organizations are moving away from process layouts in an effort to capture the benefits of product layouts

- Cellular manufacturing
- Flexible manufacturing systems
  - Automation in a flexible way



CELLULAR LAYOUTS

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, in effect, miniature versions of product layouts

Group technology: The grouping into part families of items with similar design or manufacturing characteristics

- Design Characteristics
    - Size
    - Shape
    - Function
- Manufacturing or processing characteristics
    - Type of operations required
    - Sequence of operations required

Requires a systematic analysis of parts to identify the part families.

- Divided in similar products or families
- The cells are miniature versions of products layouts
- All parts follow the same route, although minor variations are possible (e.g. skipping an operation)

Service layout

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

- Fixed position: Equipment is brought to the customers residence or office
- Process layouts: High degree of variety
- Product layout: Organized sequentially, all following the same or similar sequence.

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

- Degree of customer contact
- Degree of customization

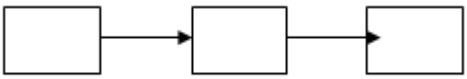
Common service layouts:

- Warehouse and storage layouts
- Retail layouts
- Office layouts

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

- The process of assigning tasks to workstations in such a way that the workstations have approximately equal time requirements
- Goal: Obtain task grouping that represent approximately equal time requirements since this minimizes idle time along the line and results in a high utilization of equipment and labour.
    - Same work load on every station
        - Difficult to form task bundles that have the same duration
            - Activities are not compatible
            - Difference in equipment requirements
            - Difference among elemental takes length, cannot always be overcome by grouping taks
            - Inability to perfectly balance a line



First and third tasks are combined 6 min, while the second task alone is also 6 min.. Ideally the first and third tasks would be combined. But that is not always possible.

- E.g. automatic car wash.: Scrubbing and drying can’t be combined, due to the need to rinse the car between the twon operations.

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

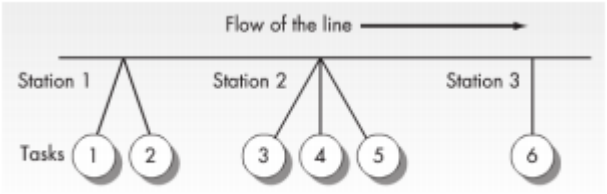
- Cycle time also establishes the **output rate of a line**

$$\text{Cycle time} = \frac{\text{Operating time per day}}{\text{Desired output rate}} \qquad \text{Output rate} = \frac{\text{Operating time per day}}{\text{Cycle time}}$$

- Assembly line configuration: grouping tasks and assigning them to stations
- Set of elementary operations (tasks) {1, 2, …, K} with task times t_k
- Cycle time c: time between the completion of 2 consecutive products

  c = takt time = available production time per day/total demand per day

  = T/d
- Assignment constraints



HOW MANY WORKSTATIONS ARE NEEDED?

The required number of workstations is a function of

- Desired output rate
- Our ability to combine tasks into a workstation

Theoretical minimum number of stations:

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

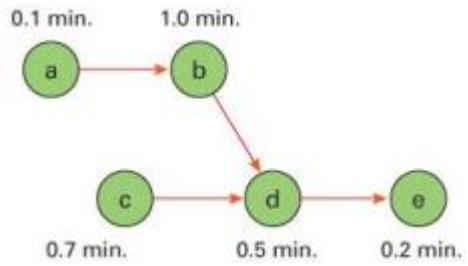
where

$N_{\min}$ = theoretical minimum number of stations

$\sum t$ = Sum of task times

Precedence diagram

A diagram that shows elemental tasks and their precedence (sequential) requirements.



To start task d, task b as well as task c have to be finished.

How to balance a line depends on how you assign tasks to workstations.

Assigning tasks to workstation

Generally there are no techniques available hat guarantee an optimal set of assignments. Instead managers employ heuristic rules.

Some Heuristic (Intuitive) Rules:

- Assign tasks in order of most following tasks
  - Count the number of tasks that follow
- 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 to step 2.

Measuring effectiveness

Balance delay (percentage of idle time)

- Percentage of idle time of a line

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

where

$$N_{actual} = \text{Actual number of stations}$$

When the calculated cycle time and the actual bottleneck station time differ, the actual bottleneck station time should be used in all idle time, efficiency, and output calculations.

The actual bottleneck time dictates the actual place of the linen whereas the calculated cycle time just an upper limit on the amount of time that can be loaded into any situation.

Efficiency: Percentage of busy time of a line.

$$\text{Efficiency} = 100\% - \text{Balance Delay}$$

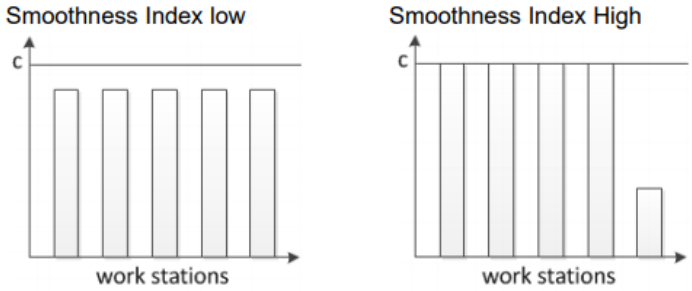
Measuring effectiveness

Smoothness Index:

- An index to indicate the relative smoothness of a given line balance.
- A smoothness index of **zero** indicates a perfect balance.

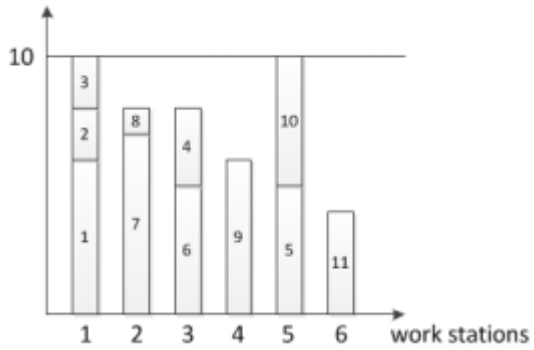
$$\textit{Smoothness Index} = \sqrt{\sum_{i=1}^{n} (\textit{maximum station time} - \textit{station time}_i)^2}$$

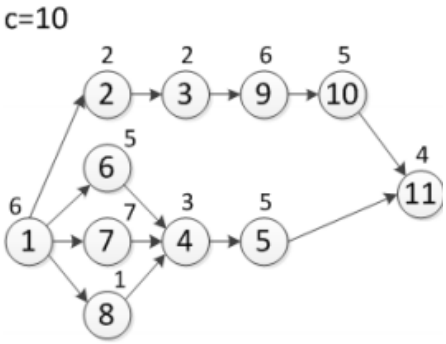
Evaluation of heuristics



Jackson 11 problem (Jackson 1956)

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

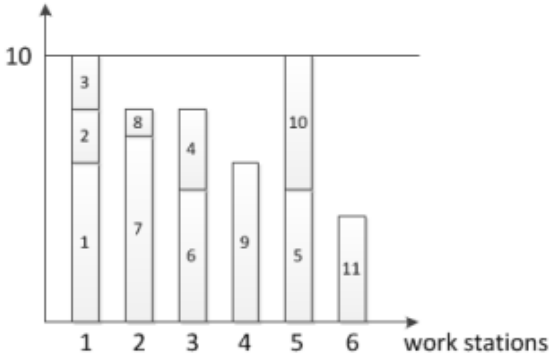




GREATEST POSITIONAL WEIGHT (HELGESON AND BIRNIE, 1961)

Task	Time	Positional weight
1	6	46
2	2	19
3	2	17
4	3	12
5	5	9
6	5	17
7	7	19
8	1	13
9	6	15
10	5	9
11	4	4

- Station 1: {1, 2, 3}
- Station 2: {7, 8}
- Station 3: {6, 4}
- Station 4: {9}
- Station 5: {5, 10}
- Station 6: {11}



EVALUATION

- Idle time = 14
- Percentage idle time = 14/60 = 23% = Balance Delay
- Efficiency = 100 - 23 = 77%

General assembly line balancing (GLAB)

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

- considers a single, straight assembly line used for only one type of product (single model)
- 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

GALBP: Integrating more practice relevant aspects:

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

Research on line balancing

- Assembly line balancing is a very broad field of research
- Many variants of ALB problems have been researched, but many research challenges remain
    - A classification of ALB problems. Boysen et al., 2007.
    - http://lib.ugent.be
- 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.**

- Measuring effectiveness
- A major objective in designing process layouts is to minimize transportation cost, distance, or time
    - Locate departments with relatively high interdependent work flow as close together as possible.

Information requirements

In designing process layouts, the following information is required:

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.

The ideal situation is to first develop a layout and then design the physical structure around it, thus permitting maximum flexibility.

From-to-chart

- From-to charts are similar to the mileage charts on roadmaps.
    - Helps you minimize the transportation costs
- They can show:
    - Distances separating pairs of work centre
    - Numbers of materials handling trips between pairs of work centres
    - Materials handling costs between pairs of work centres

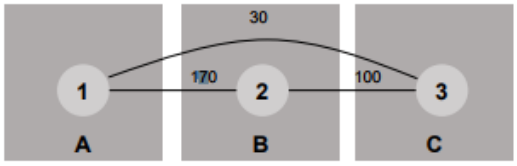
PROCESS LAYOUT PROBLEM

Distance between locations in meters

From \ To	A	B	C
A		20	40
B			30
C			

Interdepartmental work flows (loads per day)

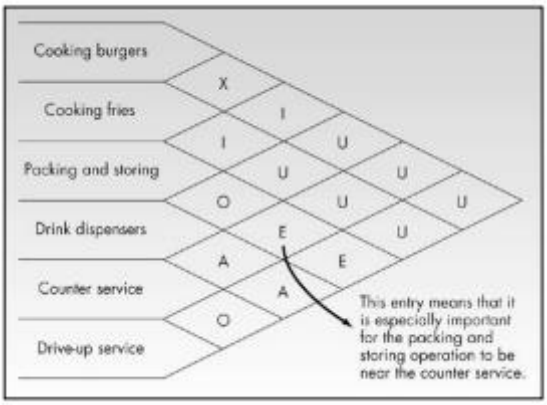
From \ To	1	2	3
1		30	170
2			100
3			



Dept.	Loads	Location	Distance (meters)	Load Distance Score
1 to 3	170	A to B	20	170 x 20 = 3,400
1 to 2	30	A to C	40	30 x 40 = 1,200
2 to 3	100	B to C	30	100 x 30 = 3,000
			Total	**7,600**

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

The need for location decisions

Location decisions arise for a variety of reasons:

- Addition of new facilities
    - As part of a marketing strategy to expand markets
    - Growth in demand that cannot be satisfied by expanding existing facilities
- Depletion of basic inputs requires relocation (uitputting)
- Shift in markets
- Cost of doing business at a particular location makes relocation attractive

Strategically important

- Closely tied to an organization's strategy
    - Low-cost
        - Locating where labour or material costs are low
    - Convenience to attract market share
- Increasing profits by increasing market shares might result in locating in high-traffic areas
- Effect capacity and flexibility
- Space constraints that limit future expansion options.
- Local restrictions my restrict my restrict certain products or services thus limiting future options for products or services.
- Represent a long-term commitment of resources
- Effect investment requirements, operating costs, revenues, and operations
    - A poor choice in location might result in excessive transportation costs
    - Shortage of qualified workers
- Impact competitive advantage
- Importance to supply chains

Objectives

Location decisions are based on:

- Profit potential or cost and customer service
- Finding a number of acceptable locations from which to choose
- Position in the supply chain
    - End: accessibility, consumer demographics, traffic patterns, and local customs are important
    - Middle: locate near suppliers or markets
    - Beginning: locate near the source of raw materials
- Web-based retail organizations are effectively location independent

Supply chain considerations

Supply chain management must address supply chain configuration:

- Number and location of suppliers, production facilities, warehouses and distribution centres

- Centralized vs. decentralized distribution:
    - Centralized distribution: Yield scale economies and gives a tighter control
    - Decentralized distribution: More responsive to local needs

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

Location options

Existing companies generally have four options available in location planning:

1) Expand an existing facility
    - Need of adequate room for expansion
    - Expansion cost re other lower than those of other alternatives
2) Add new locations while retaining existing facilities
    - Take into account what the impact will be on the total system
    - Can be a strategy to maintain market share
    - Prevent competitors from entering a market
    - Another store needs to draw more consumer and not customers who already patronize an existing store
3) Shut down one location and move to another
    - Exhausted raw materials
4) Do nothing
    - If analyses of potential locations fails to uncover benefits to expanding,..

Global: Location: facilitating factors

Two key factors have contributed to the attractiveness of globalization:

- Trade agreements
    - Reduced quotas and tariffs
    - North American Free Trade Agreement (NAFTA) – General Agreement on Tariffs and Trade (GATT) – U.S.-China Trade Relations Act –
    - EU and WTO efforts to facilitate free trade
- Technology
    - Advances in communication and information technology

BENEFITS

A wide range of benefits have accrued to organizations that have globalized operations

- Markets: More opportunities for expanding markets
- Cost savings: transportation, labour cost,..
- Legal and regulatory
- Less restrictive environmental regulations
- Financial
- Avoid currency changes
- State incentives to attract businesses
- Other: Globalization may provide new sources of ideas for products and services, new perspectives on operations, and solutions to problems

DISADVANTAGES

There are a number of disadvantages that may arise when locating globally:

- Transportation costs
- Poor infrastructure, shipping over great distances
- Security costs
- Unskilled labour
- Additional employee training may be needed
- Import restrictions
- Criticism for locating out-of-country

RISKS

Organizations locating globally should be aware of potential risk factors related to:

- Political instability and unrest can create safety issues
- Terrorism
- Economic instability might create inflation or deflation, both can negatively impact profit
- Legal regulation: may change, you could lose the key benefits
- Ethical considerations
- Cultural differences

MANAGING GLOBAL OPERATIONS

Managerial implications for global operations:

- Language and cultural differences
    - Risk of miscommunication
    - Development of trust
    - Different management styles
    - Corruption and bribery
- Increased travel (and related) costs
- Challenges associated with managing far-flung operations
- Level of technology and resistance to technological change
- Domestic personnel may resist locating, even temporarily

GENERAL PROCEDURE FOR MAKING LOCATION DECISIONS

Steps followed to make location decisions:

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

Identifying a country, a region, community, and a site

IDENTIFYING A COUNTRY

	Factors relating to foreign locations
Government	a. Policies on foreign ownership of production facilities - Local content requirements - Environment regulations - Import restrictions - Local product standards - Currency restrictions - Liability laws b. Stability issues
Cultural differences	Living circumstances for foreign workers and their dependents Ways of doing business Religious holidays/traditions
Customer preferences	Possible "buy locally" sentiment
Labor	Level of training and education of workers Work ethic Wage rates Possible regulations limiting the number of foreign employees Language differences
Resources	Availability and quality of raw materials, energy, transportation infrastructure
Financial	Financial incentives, tax rates, inflation rates, interest rates
Technological	Rate of technological change, rate of innovations
Market	Market potential, competition
Safety	Crime, terrorism threat

- Currency and exchange risks
- Low labour productivity
- Transfer pricing rules

IDENTIFYING A REGION

Primary regional factors:

- Location of raw materials
  - Necessity: Mining, farming
  - Perishability = bederfelijkheid : Freezing of fresh fruits..
  - Transportation costs
- Location of markets
  - As part of a profit-oriented company's competitive strategy
  - So not-for-profits can meet the needs of their service user
  - Distribution costs and perishability
- Labour factors
  - Cost of labour
  - Availability of suitably skilled workers
  - Wage rates in the area
- Labour productivity
  - Attitudes toward work
  - Whether unions pose a serious potential problem
  - difference in worker attitude
- Other factors: Climate and taxes may play an important role in location decisions

IDENTIFYING A COMMUNITY

- Many communities actively attempt to attract new businesses they perceive to be a good fit for the community
- Businesses also actively seek attractive communities based on such factors such as:
    - Quality of life
    - Services
    - Attitude
    - Taxes
    - Environmental regulations
    - Utilities
    - Development support

IDENTIFYING A SITE

Primary site location considerations are:

- Land
    - Cost, degree of development required
    - Soil characteristics,
    - Room for expansion
- Transportation
    - Type: access roads,..
- Zoning restrictions
    - Environmental/ legal
- Other restrictions

Multiple plant manufacturing strategies

Organizing operations:

- Product plant strategy
    - Entire products or product lines are produced in separate plants, and each plant usually supplies the entire domestic market
- Market area plant strategy
    - Plants are designated to serve a particular geographic segment of the market
    - Plants produce most, if not all, of a company's products
- Process plant strategy
    - Different plants focus on different aspects of a process e.g., automobile manufacturers – engine plant, body stamping plant, etc.
    - 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 system (GIS)

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

- Aids decision makers in
    - Targeting market segment
    - Identifying locations relative to their market potential

    - Planning distribution networks
- Portraying relevant information on a map makes it easier for decision makers to understand

SERVICE AND RETAIL LOCATIONS

Considerations:

- Nearness to raw materials is not usually a consideration
- Customer access is a
    - Prime consideration for some: Banks, restaurants, hotels, etc.
    - Not an important consideration for others: service call centers, etc.
    - Traffic volume
    - Public transportation
    - Customer safety and security
    - Parking facilities
- Tend to be profit or revenue driven, and so are
    - Concerned with demographics, competition, traffic volume patterns, and convenience
    - Manufacturers are more cost driven
- Clustering
    - Similar types of businesses locate near one another

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

EVALUATING LOCATION ALTERNATIVES

Common techniques

Locational cost-profit-volume analysis

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** (or highest profit) for the expected level of output

Assumptions

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

To compute the total cost for each alternative location:

$$\text{Total Cost} = FC + v \times Q$$

where

FC = Fixed cost

v = Variable cost per unit

Q = Quantity or volume of output

EXAMPLE: COST-PROFIT-VOLUME ANALYSIS

Fixed and variable costs for four potential plant locations are shown:

Location	Fixed Cost per Year	Variable Cost per Unit
A	$250,000	$11
B	$100,000	$30
C	$150,000	$20
D	$200,000	$35

Range of output for which each output is superior

B Superior (up to 4,999 units)

- Lowest total cost

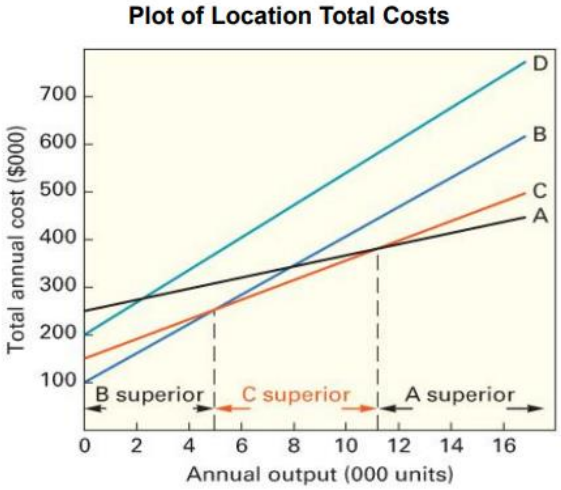
What if the expected output at a location is 800,000? C is superior.

The exact range of when alternative is superior based on output.

(zoeken naar de snijpunten via BEP, B is het best van 00 tot en 500,000 …)

C Superior (>5,000 to 11,111 units)

A superior (11,112 units and up)



$$\text{Total Cost of A} = \text{Total Cost of C}$$
$$250{,}000 + 11Q = 150{,}000 + 20Q$$
$$100{,}000 = 9Q$$
$$Q = 11{,}111.11$$

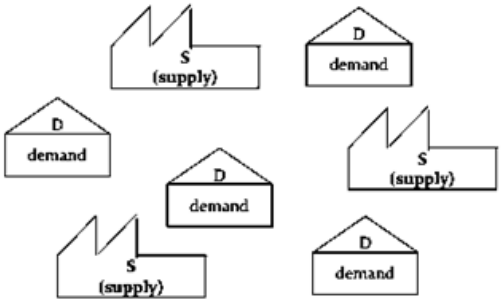
$$\text{Total Cost of C} = \text{Total Cost of B}$$
$$150{,}000 + 20Q = 100{,}000 + 30Q$$
$$50{,}000 = 10Q$$
$$Q = 5{,}000$$

Transportation model

Involves 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

- Include transportation cost per unit in cost-volume analysis

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 PROBLEM: LINEAR PROGRAMMING FORMULATION

x_{ij} = the number of units to ship from factory i to warehouse j

Decision Variables — where i = 1, 2, and 3 and j = A, B, C, and D

Minimize
$$4x_{1A} + 7x_{1B} + 7x_{1C} + 1x_{1D} + 12x_{2A} + 3x_{2B} + 8x_{2C} + 8x_{2D} + 8x_{3A} + 10x_{3B} + 16x_{3C} + 5x_{3D}$$

Subject to

Supply (rows)
$$x_{1A} + x_{1B} + x_{1C} + x_{1D} = 100$$
$$x_{2A} + x_{2B} + x_{2C} + x_{2D} = 200$$
$$x_{3A} + x_{3B} + x_{3C} + x_{3D} = 150$$

Demand (columns)
$$x_{1A} + x_{2A} + x_{3A} = 80$$
$$x_{1B} + x_{2B} + x_{3B} = 90$$
$$x_{1C} + x_{2C} + x_{3C} = 120$$
$$x_{1D} + x_{2D} + x_{3D} = 160$$
$$x_{ij} \geq 0 \text{ for all } i \text{ and } j$$

TRANSPORTATION: COMPUTER SOLUTION

- 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
- 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

- Others allow data entry in a more simple, tabular format

Factor rating

General approach to evaluating locations that includes quantitative and qualitative input

- Gives a rational basis for evaluation and facilitates comparison
- Incorporates personal opinions (qualitative) and quantitative information
- Procedure:

5. Determine which factors are relevant
6. Assign a weight to each factor that indicates its relative importance compared with all other factors.
   - Weights typically sum to 1.00
7. Decide on a common scale for all factors, and set a minimum acceptable score if necessary
8. Score each location alternative
9. Multiply the factor weight by the score for each factor, and sum the results for each location alternative
10. Choose the alternative that has the highest composite score, unless it fails to meet the minimum acceptable score

EXAMPLE: FACTOR RATING

A photo-processing company intends to open a new branch store. The following table contains information on two potential locations. Which is better?

		Scores (Out of 100)		Weighted Scores	
Factor	**Weight**	**Alt 1**	**Alt 2**	**Alt 1**	**Alt 2**
Proximity to existing source	.10	100	60	.10(100) = 10.0	.10(60) = 6.0
Traffic volume	.05	80	80	.05(80) = 4.0	.05(80) = 4.0
Rental costs	.40	70	90	.40(70) = 28.0	.40(90) = 36.0
Size	.10	86	92	.10(86) = 8.6	.10(92) = 9.2
Layout	.20	40	70	.20(40) = 8.0	.20(70) = 14.0
Operating Cost	.15	80	90	.15(80) = 12.0	.15(90) = 13.5
	1.00			70.6	82.7

Center of gravity method

Method for locating a distribution center that minimizes distribution costs

- Treats distribution costs as a linear function of the distance and the quantity shipped
- The quantity to be shipped to each destination is assumed to be fixed
- The method includes the use of a map that shows the locations of destination
- The map must be accurate and drawn to scale
- A coordinate system is overlaid on the map to determine relative locations

$$\bar{x} = \frac{\sum x_i}{n}$$

$$\bar{y} = \frac{\sum y_i}{n}$$

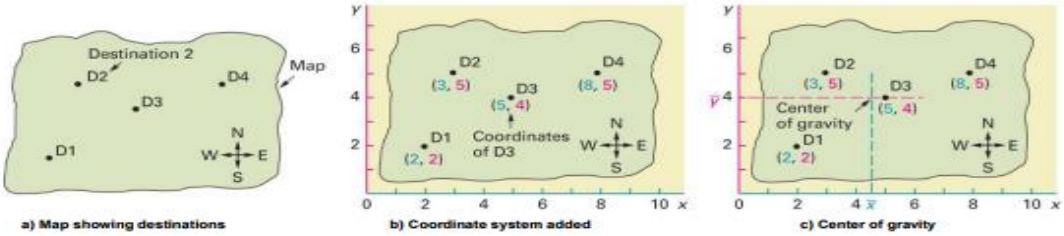
where

$x_i = x$ coordinate of destination i

$y_i = y$ coordinate of destination i

$n =$ Number of destinations

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



EXAMPLE: CENTER OF GRAVITY METHOD

Suppose you are attempting to find the centre of gravity for the problem depicted in Figure c (slide 40)

Destination	x	y
D1	2	2
D2	3	5
D3	5	4
D4	8	5
	18	16

$$\bar{x} = \frac{\sum x_i}{n} = \frac{18}{4} = 4.5$$

$$\bar{y} = \frac{\sum y_i}{n} = \frac{16}{4} = 4$$

Here, the centre of gravity is (4.5,4). This is slightly west of D3.

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 the average of the y-coordinates

$$\bar{x} = \frac{\sum x_i Q_i}{\sum Q_i}$$

$$\bar{y} = \frac{\sum y_i Q_i}{\sum Q_i}$$

where

$Q_i =$ Quantity to be shipped to destination i

$x_i = x$ coordinate of destination i

$y_i = y$ coordinate of destination i

Suppose the shipments for the problem depicted in Figure a are not all equal. Determine the centre of gravity based on the following information:

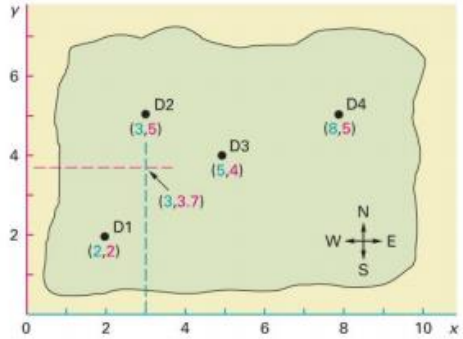
Destination	x	y	Weekly Quantity
D1	2	2	800
D2	3	5	900
D3	5	4	200
D4	8	5	100
	18	16	2,000

$$\bar{x} = \frac{\sum x_i Q_i}{\sum Q_i} = \frac{2(800)+3(900)+5(200)+8(100)}{2{,}000} = \frac{6{,}100}{2{,}000} = 3.05$$

$$\bar{y} = \frac{\sum y_i Q_i}{\sum Q_i} i = \frac{2(800)+5(900)+4(200)+5(100)}{2{,}000} = \frac{7{,}400}{2{,}000} = 3.7$$

The coordinates for the center of gravity are (3.05, 3.7).

This is south of destination D2 (3, 5).


y
6
4
2
0
2
4
6
8
10
x
D2
(3,5)
D3
(5,4)
D4
(8,5)
(3,3.7)
D1
(2,2)
N
W
E
S