Summaries modules 5 + 6

Industrial Engineering and Management

Study Association Stress
RAVELIJN BUILDING | RA1336

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Stress

Stress is the study association for Business Administration (BA), International Business Administration (IBA) and Industrial Engineering and Management (IEM) of the University of Twente. Stress was founded on May 21st, 1974. Currently, Stress has over 2100 members and is the largest UT (study) association. Stress organizes various activities to support, expand and complement all of its studies. Stress has five principles, which will greatly enhance your time as a student: Study, Meet, Practice, Develop and International. Following these, several activities are organized by the roughly 120 active members, and are partially made possible thanks to the sponsorship and participation of various companies. Moreover, we have regular contact with other business and management study associations across the Netherlands.

Education

As a study association, Stress represents its members towards the faculty. Therefore we have a Commissioner of Educational Affairs who, with help of the Education Committee, deals with everything concerning your education. From collecting summaries to handling complaints to organizing educational events. If you have any questions concerning your study, the teachers, the faculty or anything else, feel free to ask the Commissioner of Educational affairs!

Education Committee

The committee consists of representatives of every cohort. The representative of the freshmen will be introduced during the first module. This committee is aimed at forming the bridge between teachers and students and therefore, improving the quality of the study. They keep the summary database on the Stress site up to date, organise study evenings and try to keep an eye out for the quality of our education. When there are complaints from the students concerning education, about one of the courses of one of our studies for example, they will be handled by this committee.

Summaries

Next to handling complaints, we also collect and check summaries of all the courses you follow! So it does not matter if the course is in the first, fifth or eighth module, you can send your summary in and we will check if your summary will make a good addition to our collection. To hand in your summary, simply send the file to ec@stress.utwente.nl. The Education Committee will then check the summary and if it is found to be sufficient, you will be compensated for your efforts. If your summary is the first one of a course, you will receive €15. If it is the second one, €10, and for the third one you will get €5. If you think you have made a better summary than the ones online, you can also send yours in and earn €5,-. Our summary collection can be found at the bottom of the 'study' page on www.stress.utwente.nl.

Panel Meetings

The panel meetings are organised in every module to improve the education. Here, the teachers of the module together with some students discuss the module. The students are able to give their opinion about the module and what they would like to see improved. The teachers can also ask questions about the opinions of the students. This way teachers know what went right in a module and what went wrong so they can improve the module for next year. The panel meetings are for all the students which are taking the module. You can also join the feedback panel. This means that you join a group of student who attends the panel meeting each module and gives valuable feedback to the programme.

Study sessions

For some courses, Stress organises study sessions. During these afternoons or evenings one or two student assistants of the course will be present. The study sessions are free to attend and coffee, tea and snacks are provided for you by Stress. If you think a study session will be valuable for a course you are following, please contact the Commissioner of Educational Affairs or the Education Committee. They will check if there is more demand for a study evening for this course and act accordingly.

Complaints

If you have a complaint, you can submit it at the ‘Study’ page on www.stress.utwente.nl or talk to someone of the Education Committee. However, if you feel it is a really important complaint or you want to explain it personally, you can come to the Stress room and talk to the Commissioner of Educational Affairs or send an email. We will then contact the programme management team and discuss what actions can be taken. They value bundled complaints greatly because it tells them a lot more when multiple people have the same complaint, this is the most important reason to always voice your opinion.

Ordering Books

For the first module, you can order your books during the Kick-In. For the following modules, you will have to order them by yourself. You can do this online, at our website. The only requirement to order the books is that you are a member of Stress.

To order books online you have to go to the ‘Study’ page on www.stress.utwente.nl. On the left of the screen you find a header: ‘BOOKSALE’, and below the option: ‘Order your books’; select this option. Next, you can use the dropdown menus to select your study and module. Once you have chosen the correct options, press ‘To booklist’. After this, you can select all the books you would like to order, and then proceed to 'Checkout. After paying, the books will be shipped to the address you enter.

For any questions about the books you need, the ordering of the books or anything else book-related, you can send an email to books@stress.utwente.nl.

Tutor platform

If you are having trouble studying for a course, we have the tutor platform to provide you with the right student for your struggles. We have a wide variety of students who have gone before you and who are willing to help you out for a small compensation. Send an email to tutor@stress.utwente.nl and mention your study, study-year, course you need help with, how many hours you need and any requirements you might have for the tutor. The payment of the tutor can be negotiated but keep in mind that students get paid €10 to €15 by the university when working as a teaching assistant, and you have to pay for it yourself.

The other way around, we are always looking for new tutors. If you are interested in joining our tutor pool let us know. We will add you to the WhatsApp group and you can reply to students asking for tutoring.

HELP!

Often, students do not know where to go with any problems, either study-related or personal. Here you find some information about the most common places to find help.

Study advisor

The study advisor is not only there to answer all your questions about your study, but also there to help you with any personal conditions or other issues that might affect you or your study progress. If you have any problem at all, go see your study advisor. Even if they are not the person who can help you, they can send you to someone who can. Every talk with study advisors is confidential and they will always do their best to help you. You can make an appointment with the study advisors on www.bms.planner.utwente.nl. The study advisors for IEM are Cornelis ten Napel and Ellen van Zeijts. The office of Cornelis is RA3246 and the office of Ellen is RA3256. Their emails are c.tennapel@utwente.nl and e.w.g.vnzeijts@utwente.nl.

Red desk / Student Affairs Coaching & Counselling

If your study and personal life are all on track, this bit of information might not be really relevant for you. But if it is not the case, when your study is completely going the wrong way, or you find it hard to adapt to living away from your parents or you have a difficult situation back at home, the Student Affairs Coaching & Counselling, also called the 'Red Desk', is the place where they can help you. Every possible question about study or personal issues will be answered here, or you will be forwarded to a trained professional. The Red Desk can be contacted at sacc@utwente.nl and is located in the Vrijhof (building 47), third floor, room 311.

Become active at Stress!

Next to your study, you can become an active member of our association! Stress offers many different committees which have organisational tasks or supporting tasks. On our website, you can check out all the committees from Stress. To find out which committee suits you best, email the Commissioner of Internal Affairs at internal@stress.utwente.nl.

Member Initiative

Have you always wanted to organize something big, but never had the resources? We appreciate initiatives from our members! So, if you have a clever idea for something within Stress or the committees, please contact us and we can see what is possible.

More information about Stress

Do you want to know more about Stress? Or do you want to check out our website and social media? Make sure to scan the QR code:

Module 5 overview: Finance for Engineers

! Disclaimer: always check what you need to study corresponds with the content of the summaries, courses can be changed which could cause changes in study material for your exams

Below you find information about which courses you have this module, and about the summaries for this module. If you made a summary for a course this module you can send them to education@stress.utwente.nl and depending on how many summaries we have for this course you will receive compensation for your work.

Courses

- Accounting and Finance
- Option Pricing
- Methodology
- Skills
- Project

Summary 1

Course: Finance & Option Pricing*
Book: Brealey, R. A., Myers, S. C., & Allen, F. (2013). *Principles of Corporate Finance.* New York, United States: McGraw-Hill Education.
Chapters: 1-4, 7-9, 17, 18, 20, 21, 28
Year the summary was received: 2015/2016

Summary 2

Course: Methodology*
Book: Saunders, M. N. K., Lewis, P., & Thornhill, A. (2019). *Research Methods for Business Students.* Pearson
Chapters: 5, 8, 9, 10, 11, 12, 13,
Year the summary was received: 2021/2022

* There is another summary available on www.stress.utwente.nl

Summary 1: Finance & Option Pricing

Chapter 1 Goals and Governance of the Firm

1.1 Corporate Investment and Financing Decisions

Financial assets/securities: Claims on assets/cash flows in return for money.

Investment decisions

CAPEX: Capital expenditure; investments in (in)tangible assets.

Finance decisions

Capital structure: The choice between debt and equity.

Pay-out decision: The decision to either pay dividends or repurchase shares.

1.2 The Financial Goal of the Corporation

Effective managers make decisions that increase the value of shares and the stockholder's wealth.

The Investment Trade-off

Investment trade-off is the trade-off between either paying the shareholders or investing in real assets.

Opportunity cost of capital (OCC): Minimum rate of return an investment should give, so that shareholders will earn more money than when spending money elsewhere.

Should Managers Look After the Interests of Their Shareholders?

Managers should look after the interests of the company, which is often the same, but not anything goes.

Agency Problems and Corporate Governance

Conflicts between shareholders' and managers' objectives create **agency problems**. Its **agency costs** are incurred when managers do not attempt to maximise firm value and when shareholders incur costs to monitor the managers and constrain their actions.

Chapter 2 How to Calculate Present Values

2.1 Future Values and Present Values

Calculating Future Values

Compound interest: Interest earned on initial investment plus interest. Grows at **compound rate**.

$$\text{Future value } (FV) \text{of } N = N * (1 + r)^t$$

Calculating Present Values

$$\text{Present value } (PV) = \frac{C_t}{(1+r)^t}; \text{where } C_t \text{ is the intended } FV$$

Valuing an Investment Opportunity

When valuing an opportunity you need to compare the rate of return of an investment with the OCC. Rate of return simply is the expected profit divided by the investment. Cost of capital is the ROR that shareholders could get by investing on **same level of risk** elsewhere. When calculating the PV in this case, use the OCC as *r*.

Net Present Value

Net Present Value (NPV) is the present value minus the investment.

$$NPV = C_0 + \frac{C_1}{(1+r)}; \text{where } C_0 \text{ is the investment}$$

Present Values and Rates of Return

Investments can be justified by either one of the following two rules:

- *Net present value rule:* Accept investments that have positive net present values.
- *Rate of return rule:* Accept investments that offer ROR in excess of their OCC.

Calculating Present Values When There Are Multiple Cash Flows

$$\text{Multiple cash flows } PV = \sum_{t=1}^{T} \frac{C_t}{(1+r)^t}; \text{also called the } \textbf{discounted cash flow } (\boldsymbol{DCF})$$

.

Thus, the NPV with multiple cash flows is as follows:

$$NPV = C_0 + \sum_{t=1}^{T} \frac{C_t}{(1+r)^t}$$

2.2 Looking for Shortcuts – Perpetuities and Annuities

Perpetuities are bonds that under no obligation have to be repaid but that offer a fixed income for each year to perpetuity. Its PV is equal to the promised annual payment divided by annual ROR:

$$PV = \frac{C}{r}; \text{where C is the promised annual payment}$$

In the case a perpetuity is starting to make payments after *t* years, the PV is as follows:

$$PV = C * \frac{1}{r(1+r)^t}$$

How to Value Annuities

Annuities are assets that pay a fixed sum each year for a specified number of years, e.g. an equal payment house mortgage. Its present value is calculated as follows:

$$PV \text{ of a } t - \text{year annuity} = C * \left[\frac{1}{r} - \frac{1}{r(1+r)^t}\right]$$

Valuing Annuities Due

Annuity due means the payments start immediately, instead of the end of the year. An annuity due is worth (1 + r) times the value of an ordinary annuity.

Future Value of an Annuity

The future value of annuity is the present value of annuity multiplied by $(1 + r)^t$, so:

$$\text{Future value} = C * [t - \text{year ann.} * (1+r)^t] = C * \left[\frac{(1+r)^t - 1}{r}\right]$$

2.3 More Shortcuts – Growing Perpetuities and Annuities

Growing Perpetuities

If the perpetuities grow every year, another formula has to be used to value the growing perpetuity:

$$PV \text{ of growing perpetuity} = \frac{C_1}{r-g}; \text{where g is the growth rate and } r > g$$

Growing Annuities

When annuities grow yearly, the formula for the present value is as follows:

$$PV \text{ of growing annuity} = C * \frac{1}{r-g} * \left[1 - \frac{(1+g)^t}{(1+r)^t}\right]$$

2.4 How Interest Is Paid and Quoted

If an institution offers an **annual percentage rate** (**APR**) of e.g. 10%, the monthly rate would be 10/12 = 0,83%. Though, because the interest will be used as new money for the interest, the *effective* annual rate will be $1{,}0083^{12}$ = 1,1043; so 10,43%. Formula:

$$\text{Effective annual rate} = (1 + \frac{r}{m})^m; m \text{ is amount of compounds per year}$$

Continuous Compounding

In case the compounding is continuously, the formula becomes:

$$\text{Effective annual rate} = e^{rt}$$

$$PV \text{ of } t - \text{year annuity with with cont. comp. rate } r = C * \left[\frac{1}{r} - \left(\frac{1}{r} * \frac{1}{e^{rt}}\right)\right]$$

3 Valuing Bonds

3.1 Using the Present Value Formula to Value Bonds

A **bond** gives regular interest payments yearly, and the bonds **face value**, or **principal**, plus interest when it matures (the end of the bond).

A Short Trip to Paris to Value a Government Bond

French government bonds (OATs) pay interest once a year. This interest's amount is called the bond's **coupon**. The PV of this bond is the sum of the PV of the coupons and the PV of the final payment, which is as follows:

$$PV(bond) = C * \left[\frac{1}{r} - \frac{1}{r(1+r)^t}\right] + \frac{F}{(1+r)^t}; C \text{ is coupon and } F \text{ final payment (principal)}$$

Yield to maturity (YTM) is simply the discount rate at which the sum of all future cash flows from the bond (coupons and principal) is equal to the price of the bond. The **current yield** is the immediate yield on your investment, being the coupon payment divided by the PV of the bond.

$$PV = \frac{1}{1+r} + \frac{1}{(1+r)^2} + \cdots + \frac{1}{(1+r)^t}; \text{solve for } r\ (YTM)$$

A **premium** bond is priced above its face value. Its investors face a capital loss of the life of the bond, so the YTM is less than the current yield. **Discount** bonds are priced below face value. Investors face a capital gain, so the YTM is greater than the current yield.

On to the United States: Semi-annual Coupons and Bond Prices

Works the same as described above, only difference here is that the pay-out frequency is semiannually. Divide the coupons and YTM by two.

3.2 How Bond Prices Vary with Interest Rates

If bond prices increase, its YTM drops, and the other way around. Long-term bonds are much more sensitive to interest rate fluctuations than short-term bonds.

Duration and Volatility

When we need to calculate which of two bonds is the longer-term investment, we must look at the proportion of the cash flows that occur at maturity, when the face value is paid off. The longer *average* time is the longer-term investment. This investment benefits most from a fall in yields. A better way is to calculate it with the (Macaulay) **duration**, the weighted average of the times to each of the cash payments. Its formula is:

$$\text{Duration} = \frac{1 * PV(C_1)}{PV} + \frac{2 * PV(C_2)}{PV} + \cdots + \frac{T * PV(C_T)}{PV}$$

Volatility (modified duration) measures the percentage change in bond price for a 1 percentagepoint change in yield. The formula is as follows:

$$\text{Volatility}(\%) = \frac{\text{duration}}{1 + \text{yield}}$$

3.3 The Term Structure of Interest Rates

The **term structure of interest rates** is the relationship between short- and long-term interest rates. **Spot rate** is the *t*-year rate of interest, r_t. Calculations with this spot rate work the same as usual.

Spot Rates, Bond Prices, and the Law of One Price

The law of one price states that the same commodity must sell at the same price in a wellfunctioning market.

Measuring the Term Structure

One can think of the spot rate r_t as the rate of interest on a bond that makes a single payment at time t. That is being used in **stripped bonds** (strips), which are parts of e.g. coupon bonds.

3.4 Explaining the Term Structure

Expectations Theory of the Term Structure

Expectations theory states that in equilibrium investment in a series of short-maturity bonds must offer the same expected return as an investment in a single long-maturity bond. It is tempting to borrow short-term if its rates are significantly lower than long-term, but theoretically the two will be in equilibrium.

Introducing Risk
Every investment has its own risk-level. When investing, one must always balance the return with the risk.

Inflation and Term Structure
Inflation obviously also plays a role in the choice of your investment.

3.5 Real and Nominal Rates of Interest
Consumer Price Index (CPI) is the index to measure inflation. **Real** cash flow, or purchasing power, is the nominal cash flow divided by the inflation rate. Formula for the real rate of return:

$$1 + r_{real} = \frac{1 + r_{nominal}}{1 + r_{inflation}}$$

Indexed Bonds and the Real Rate of Interest
Indexed bonds make cash payments linked to inflation.

What Determines the Real Rate of Interest?
Real rate of interest depends on people's willingness to save and the opportunities for productive investment. Short- and medium-term real interest rates are affected by the monetary policy of central banks.

Inflation and Nominal Interest Rates
Fisher's theory: A change in the expected inflation rate causes the same proportionate change in the *nominal* interest rate; it has no effect on the required real interest rate. Formula is as described in section 3.5.

Chapter 4 The Value of Common Stocks
4.1 How Common Stocks Are Traded
Sales of shares to raise new capital are said to occur in the **primary market**. Purchases and sales of existing stocks take place on the **stock exchange**. Besides those markets, there are computer networks called **electronic communication network**s (ECN) that connect traders with each other.

4.2 How Common Stocks Are Valued
A company's **equity book value** is its *normal* book value minus its liabilities. Book values are historical costs that do not incorporate inflation, and usually exclude intangible assets.

Valuation by Comparables
Valuation by comparables: Identifying a sample of similar firms as potential *comparables*. Then examine how much investors in the comparables are prepared to pay per dollar of earnings or book assets. They see what the business would be worth when traded at comparables' price-earnings (P/E) or price-to-book-value (P/B) ratios.

Stocks Prices and Dividends
The PV of the share of stock equals the PV of the expected future dividends per share. The ROR that investors expect from a share over a year is the expected dividend plus the appreciation of the share:

$$\text{Expected return } r = \frac{DIV_1 + P_1 - P_0}{P_0}\text{; where } P_0 \text{ is the shareprice, } P_1 \text{ price after a year}$$

This OCC rate r is also called the **market capitalisation rate** or **cost of equity capital**. Stocks with essentially the same risks are in the same **risk class**.

For calculating the price with multiple years, look at the following formula:

$$P_0 = \frac{DIV_1 + P_1}{1+r}; \text{thus } P_1 = \frac{DIV_2 + P_2}{1+r}; \text{so } P_t = \frac{DIV_{t+1} + P_{t+1}}{1+r};$$

$$\text{and } P_0 = \frac{1}{1+r} * \left(DIV_1 + \frac{DIV_2 + P_2}{1+r}\right)$$

In other words, the general stock price formula is as follows:

$$P_0 = \sum_{t=1}^{H} \frac{DIV_t}{(1+r)^t} + \frac{P_H}{(1+r)^H}; \text{where H is the final year}$$

If *H* becomes a large number, the cumulative dividends become very high, while the present value of the terminal price approaches zero. Therefore, we can forget about the terminal price and express today's price as the present value of a perpetual stream of cash dividends:

$$P_0 = \sum_{t=1}^{\infty} \frac{DIV_t}{(1+r)^t}$$

This formula is also called the **dividend discount model** or DCF.

4.3 Estimating the Cost of Equity Capital

When we forecast a constant growth rate for a company's dividends, the PV is as follows:

$$P_0 = \frac{DIV_1}{r-g}, \text{thus } r = \frac{DIV_1}{P_0} + g; \text{where } r > g \text{ and } \frac{DIV_1}{P_0} \text{ the } \textbf{dividend yield}$$

Using the DCF Model to Set Gas and Electricity Prices

The **pay-out ratio** is the ratio of dividends to earnings per share (EPS), thus the percentage of the earnings that is paid back as dividend. The **plowback ratio** is the opposite, namely the percentage that is ploughed back into business. **Return on equity** (ROE) is the ratio of earnings per share to book equity. Now we know the ROE and the plowback ratio, we can calculate the dividend growth rate *g*, by multiplying those two. In formulas, it looks like this:

$$\text{Plowback ratio} = 1 - \text{payout ratio} = 1 - \frac{DIV}{EPS}; \frac{DIV}{EPS} \text{ is called ratio of dividends to } EPS$$

$$ROE = \frac{EPS}{\text{book equity per share}}; \text{also called ratio of } EPS \text{ to book equity}$$

$$g = plowback\ ratio * ROE$$

Dangers Lurk in Constant-Growth Formulas

Since we cannot always estimate *r* properly, try to use sample of equivalent-risk securities. Also, resist the temptation to apply the formula to firms having high current rates of growth.

DCF Models with Two Stages of Growth:

In case the ROE changes after some years, the growth rate will change along. Therefore, the following formula applies:

$$P_0 = \left[\frac{DIV_1}{1+r} + \frac{DIV_2}{(1+r)^2} + \frac{DIV_3}{(1+r)^3}\right] + \frac{1}{(1+r)^3} * \frac{DIV_4}{r-g}$$

where the first three 'DIVs' are the first stage, and the fourth DIV is the second stage.

Sometimes we already know the P_0 and we have to estimate r, other times we can calculate P_0 by knowing the rate r.

4.4 The Link Between Stock Price and Earnings per Share

Investors separate *growth* stocks from *income* stocks. Growth stocks are for capital gains, while income stocks are bought primarily for dividends.

In general, we can think of stock price as the capitalised value of average earnings under a no-growth policy, plus the **net present value of growth opportunities** (PVGO):

$$P_0 = \frac{EPS_1}{r} + PVGO; \text{thus the earnings} - \text{price ratio } \frac{EPS_1}{P_0} = r * \left(1 - \frac{PVGO}{P_0}\right)$$

In words: share price = present value of level stream of earnings + present value of growth opportunities.

4.5 Valuing a Business by Discounted Cash Flow

Valuing the Concatenator Business

The **free cash flow** (FCF) is the amount of cash that a firm can pay out to investors after paying for all investments necessary for growth, thus the pay-out rate multiplied by the earnings.

Valuation Format

The value of a business is usually computed as the discounted value of free cash flows out to a *valuation horizon (H)*, plus the discounted forecasted value of the business at the horizon:

$$PV = \frac{FCF_1}{1+r} + \frac{FCF_2}{(1+r)^2} + \cdots + \frac{FCF_H}{(1+r)^H} + \frac{PV_H}{(1+r)^H}; \text{first part is } PV(FCF), \text{last part } PV(HV)$$

Estimating Horizon Value

Different ways of estimating horizon value are:

- DCF formula: $PV_H = \frac{FCF_H}{r-g}$, after which this PV_H is discounted: $\frac{PV_H}{(1+r)^H}$
- P/E ratios: $PV_H = \frac{1}{(1+r)^H} * \frac{P}{E} * \text{earnings}$
- Market-book ratios: $PV_H = \frac{1}{(1+r)^H} * \text{market book ratio} * \text{asset value}$

A Further Reality Check

There comes a time for every company when its competitors are just as smart and efficient as you, and introductions of new products or attempts to expand sales of existing products triggers intense resistance from them. That time is the horizon after which the PVGO is zero. In formula, when:

$$PV_H = \frac{earnings_{H+1}}{r}$$

7 Introduction to Risk and Return

7.1 Over a Century of Capital Market History in One Easy Lesson

Risk premium is the difference between nominal returns of two different-risk-stocks.

Arithmetic Averages and Compound Annual Returns

Moral: If the cost of capital is estimated from historical returns or risk premiums, use arithmetic averages, not compound annual rates of return. For an example, see p. 163.

Using Historical Evidence to Evaluate Today's Cost of Capital

Market return r_m is the return investors would forgo by investing in a proposed project. It is estimated as the risk-free interest rate r_f and a premium for risk. So, in formula:

$$r_m = r_f + \text{normal risk premium}$$

7.2 Measuring Portfolio Risk

Variance and Standard Deviation

Expected return r, also known as the *mean*, is the chance of having a return multiplied by the return. In other words:

$$\text{Expected return} = \sum_{i=1}^{k} \rho_i * \tilde{r_i}$$

Variance, also known as σ^2, defines the spread of the rate. Its formula is as follows:

$$\text{Variance } \sigma^2 = \sum_{i=1}^{k} \rho_i * (\tilde{r}_i - r)^2$$

The standard deviation σ is simply the square root of the variance.

How Diversification Reduces Risk

Risk that can potentially be eliminated by diversification is called **specific risk**. Risk that is not avoidable is called **market risk**.

7.3 Calculating Portfolio Risk

The portfolio variance is the sum of all 'combination variances' of the stocks. For two stocks, that is:

$$\text{Portfolio variance} = x_1{}^2\sigma_1{}^2 + x_2{}^2\sigma_2{}^2 + 2(x_1x_2\rho_{12}\sigma_1\sigma_2); \text{where } \rho_{12}\sigma_1\sigma_2 \text{ is the covariance } \sigma_{12}$$

Limits to Diversification

In case we have a portfolio in which equal investments are made in each of *N* stocks, the portfolio variance is as follows:

$$\text{Portfolio variance} = \frac{1}{N} * \text{average variance} + \left(1 - \frac{1}{N}\right) * \text{average covariance}$$

In other words, as *N* increases, the portfolio variance steadily approaches the average covariance.

7.4 How Individual Securities Affect Portfolio Risk

Principle theme: *The risk of a well-diversified portfolio depends on the market risk of the securities included in the portfolio*.

Market Risk is Measured by Beta

The sensitivity of an individual security to market movements is called **beta** (β). In other words, when a stock has a beta of e.g. 0,8, it means that when the market rises with an extra 1%, this specific stock rises with 0,8%.

Why Security Betas Determine Portfolio Risk

A statistician would define the beta of stock *i* as follows:

$$\beta_i = \frac{\sigma_{im}}{\sigma_m^2} = \frac{\rho_{12}\sigma_1\sigma_2}{\sigma_m^2}$$

7.5 Diversification and Value Additivity

Diversification does not add to a firm's value or subtract from it. The total value is the sum of its parts. Thus, PV(AB) = PV(A) + PV(B).

Chapter 8 Portfolio Theory and the Capital Asset Pricing Model

8.1 Harry Markowitz and the Birth of Portfolio Theory

Combining Stocks into Portfolios

The best portfolio has the highest expected return with the lowest risk. Portfolios that offer the highest expected return for any level of risk are called **efficient portfolios**.

We Introduce Borrowing and Lending

When borrowing money and spending it on portfolios, there is a ratio for getting the best efficient portfolio. This ratio is called the **Sharpe ratio**. Its formula is as follows:

$$\text{Sharpe ratio} = \frac{r - r_f}{\sigma}$$

The higher the ratio, the higher the ratio of risk premium to standard deviation.

8.2 The Relationship Between Risk and Return

The **security market line** is the a sloping line in a return on investment vs. beta graph, along which all investments must plot. In words: expected risk premium stock=beta * expected risk premium market

$$r - r_f = \beta(r_m - r_f); \text{ thus expected return } r = r_f + \beta(r_m - r_f)$$

This is also called the **capital asset pricing model** (CAPM).

Review of the Capital Asset Pricing Model

1. Common stock portfolios that offer the highest expected return for a given standard deviation are known as efficient portfolios.
2. If an investor can borrow at the risk-free rate of interest, the portfolio that offers the highest ratio of risk premium to standard deviation is the best.
3. Everyone's got different information and assessments, else, everyone should hold the market portfolio.
4. Look at the risk of a stock at its contribution to portfolio risk, not isolated.
5. A stock's sensitivity to changes in the value of the market portfolio is known as beta.

8.4 Some Alternative Theories

Arbitrage Pricing Theory

Arbitrage pricing theory (APT) assumes that each stock's return depends partly on pervasive macroeconomic influences or *factors* and partly on events that are unique to that company, *noise*. Moreover, the return is assumed to obey the following simple relationship:

$$\text{Return} = a + b1(r_{factor\ 1}) + b2(r_{factor\ 2}) + b3(r_{factor\ 3}) + \cdots + \text{noise}$$

These factors could be anything, e.g. oil price factors, interest-rate factors, and so on.

Arbitrage pricing theory states that the expected risk premium on a stock depends on the expected risk premium associated with each factor and the stock's sensitivity of each of the factors (b_1 etc.):

$$\text{Expected risk premium } r - r_f = b_1(r_{factor\,1} - r_f) + b_2(r_{factor\,2} - r_f) + \cdots$$

The arbitrage we have described applies to well-diversified portfolios, where the specific risk has been diversified away.

The Three-Factor Model

To estimate expected returns with the APT, you first need to follow three steps:

1. Identify a reasonable short list of macroeconomic factors that could affect stock returns.
2. Estimate the expected risk premium on each of these factors ($r_{\text{factor 1}}$-r_f, etc.).
3. Measure the sensitivity of each stock to the factors (b_1, b_2, etc.).

The Fama-French three-factor model looks like this:

$$r - r_f = b_{market}(r_{market\,factor}) + b_{size}(r_{size\,factor}) + b_{book-to-market}(r_{book-to-market\,factor})$$

Chapter 9 Risk and the Cost of Capital

9.1 Company and Project Costs of Capital

Company cost of capital: The expected return on a portfolio of all the company's existing securities. It is the appropriate discount rate for the firm's average-risk projects.

Debt and the Company Cost of Capital

The cost of capital is estimated as a blend of *cost of debt* and *cost of equity*. They values of those two add up to overall firm value. It is also called the **weighted-average cost of capital** (WACC). The formula is:

$$\text{Company cost of capital} = r_D * \frac{D}{V} + r_E * \frac{E}{V}$$

Interest is tax-deductible expense for corporations, therefore the after-tax WACC is:

$$\text{After} - \text{tax } WACC = (1 - T_c) r_D * \frac{D}{V} + r_E * \frac{E}{V}$$

9.2 Measuring the Cost of Equity

Estimating Beta

The beta is the slope of the line through the market and stock return-dots in a scatter diagram. R^2 measures the proportion of the total variance in the stock's returns that can be explained by market movements. The rest is diversifiable company risk. A beta has a standard error, with which a confidence interval can be set up.

The Expected Return on Union Pacific Corporation's Common Stock

There are two ways of estimating the risk-free rate for cash flow long time in the future:

1. Simply use a long-term risk-free rate in the CAPM formula. In this case, the market risk premium must be restated as the average difference between market returns and returns on *long-term* risk-free rates.
2. Forecast the expected return over the life of the project.

Union Pacific's Asset Beta
The **asset beta** is the blend of the separate betas of debt and equity:

$$\text{Asset beta } \beta_A = \beta_D\left(\frac{D}{V}\right) + \beta_E\left(\frac{E}{V}\right)$$

9.3 Analysing Project Risk
Companies that specialise in one activity are called *pure-play* companies. *Conglomerates* diversify into several unrelated industries.

What Determines Asset Betas?
Cyclicality: Firms whose revenues and earnings are strongly dependent on the state of the business cycle (cyclical firms) tend to be high-beta firms.

Operating Leverage: A production facility with high fixed costs has high *operating leverage*, which means a high asset beta.

$$\beta_{assets} = \beta_{revenue}\left[1 + \frac{PV(fixed\ cost)}{PV(asset)}\right]$$

Other Sources of Risk: If either the risk-free rate or the market risk premium changes, *r* will change and so the project value. Therefore, a project with very long-term cash flows will have a high beta, even though it may not have high operating leverage and cyclicality.

Avoid Fudge Factors in Discount Rates
If a project has been forecasted too pessimistically or optimistically, the expected *cash flow* should be adjusted, not the cost of capital.

9.4 Certainty Equivalents – Another Way to Adjust for Risk
Valuation by Certainty Equivalents
A **certainty-equivalent cash flow** (CEQ) is a cash flow which has the same present value as an expected but *uncertain* other cash flow. In formula:

$$PV = \frac{CEQ_t}{(1 + r_f)^t}$$

So there are two ways to value a risky cash flow:

1. Discount the risky cash flow at a *risk-adjusted discount rate r* that is greater than r_f.
2. Find the CEQ and discount at the risk-free interest r_f. When using this method, you need to ask, what is the smallest *certain* payoff for which I would exchange the risky cash flow?

Chapter 17 Does Debt Policy Matter?

17.1 The Effect of Financial Leverage in a Competitive Tax-free Economy

A company's levered when, next to having equity, it also borrows money. Its stockholders face the benefits and costs of **financial leverage**, or *gearing*.

Enter Modigliani and Miller

Modigliani and Miller's proposition 1: "The market value of any firm is independent of its capital structure; it is determined on the left-hand side of the balance sheet – not by the proportions of debt and equity securities issued to buy the assets.

17.2 Financial Risk and Expected Returns

Expected return on assets r_A is equal to the expected operating income divided by total market value:

$$r_A = \frac{\text{expected operating income}}{\text{market value of all securities}}$$

The expected return on a portfolio consisting of *all* of a company's securities is:

$$r_A = \left(\frac{D}{D+E} * r_D\right) + \left(\frac{E}{D+E} * r_E\right); \text{is the same as WACC (chapter 9)}$$

Therefore, the return on equity is:

$$r_E = r_A + (r_A - r_D) * \frac{D}{E}$$

Proposition 2

MM's proposition 2: The expected ROR on the common stock of a levered firm increases in proportion to the *(D/E)*-ratio, expressed in market values; the rate of increase depends on the spread between r_A and r_D. When a firm is unlevered, equity investors demand a return of r_A. When it is levered, they require a premium of $(r_A - r_D)*D/E$ to compensate for the risk.

If r_A is calculated for a certain capital structure, this return on assets should stay the same when switching to other capital structure. Therefore:

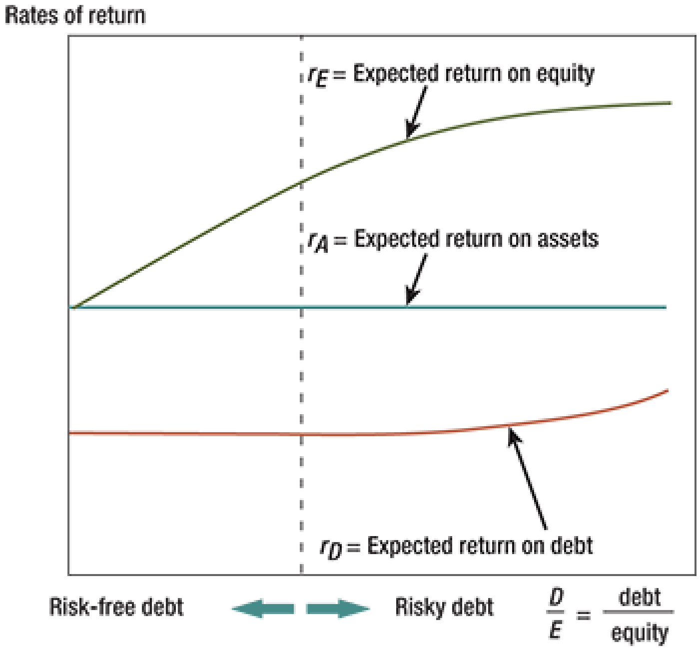
$$r_D * \frac{D}{V} + r_E * \frac{E}{V} \text{ must stay the same, only returns on equity and debt can change, and } \frac{\mathrm{D}}{\mathrm{E}} \text{ ratio}$$

How Changing Capital Structure Affects Beta

Just as the r_A must stay the same before and after changing capital structure, so must the $ß_A$. Again, betas of both equity and debt can change, as well as the D/E ratio. Remember, portfolio beta is:

$$\beta_A = \beta_{\text{portfolio}} = \beta_D * \frac{D}{V} + \beta_E * \frac{E}{V}$$

17.3 The Weighted-Average Cost of Capital



Two Warnings

Warning 1: Shareholders want management to increase the firm's value. They are more interested in being rich than in owning a firm with a low WACC.

Warning 2: Trying to minimise the WACC seems to encourage logical short circuits, which are not true. *(Example p. 438)*.

Rates of Return on Levered Equity – The Traditional Position

The traditional position suggest that r_E rises slowly in the beginning – on the debt/equity graph – but faster when firms borrow excessively.

17.4 A Final Word on the After-Tax Weighted-Average Cost of Capital

In many countries, interest paid on a firm's borrowing can be deducted from taxable income. Thus the *after-tax* weighted-average cost of capital is:

$$\text{After} - \text{tax WACC} = r_D(1 - T_c) * \frac{D}{V} + r_E * \frac{E}{V}$$

Chapter 18 How Much Should a Corporation Borrow?

18.1 Corporate Taxes

Since interest can be deducted from taxable income, a certain amount of money can be saved by having debt instead of equity. This amount of money is called the **tax shield**. It's formula is as follows:

$$\text{PV(tax shield)} = \frac{\text{corporate tax rate} * \text{interest payment}}{\text{expected return on debt}} = \frac{T_C r_D D}{r_D}; \text{with D amount borrowed}$$

How Do Interest Tax Shields Contribute to the Value of Stockholders' Equity?

MM's proposition 1 amounts to saying that the value of a firm's assets does not depend on how debt and equity are divided. But with tax included, it might change.

MM and Taxes

A version of MM's proposition 1 as corrected to reflect corporate income taxes is:

$$\text{Value of firm} = \text{value if all} - \text{equity} - \text{financed} + \text{PV(tax shield)}$$

Thus, in the special case of fixed, permanent debt:

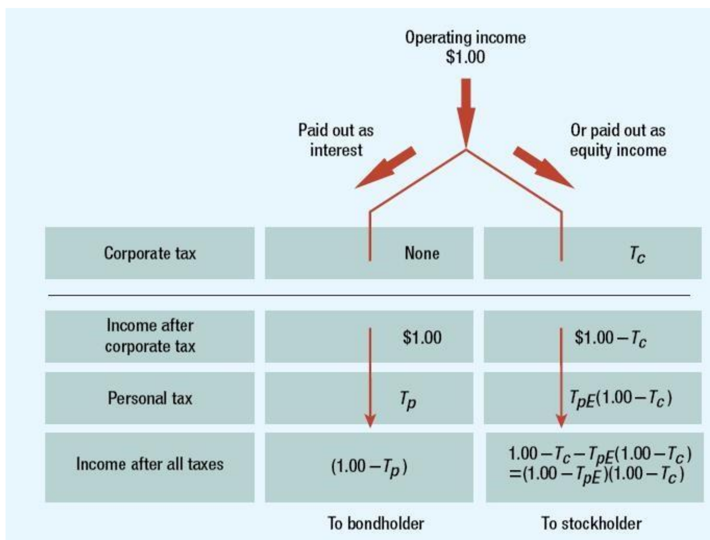
$$\text{Value of firm} = \text{value if all} - \text{equity} - \text{financed} + T_c D$$

There are several reasons why our calculations overstate the value of interest tax shields. First, it is wrong to think of debt as fixed and perpetual; a firm's ability to carry debt changes over time as profits and firm value fluctuate. Second, many firms face marginal tax rates less than 35%. Third, you cannot use interest tax shields unless there will be future profit to shield-and no firm can be absolutely sure of that. Since there is no such thing as a money machine, this cannot be true. Two reasons why could be: 1) The system of corporate *and personal* taxation might uncover a tax disadvantage; 2) Perhaps firms that borrow incur other costs – bankruptcy costs, for example.

18.2 Corporate and Personal Taxes

When personal taxes are introduced, the firm's objective is no longer to minimise the *corporate* tax bill; it should try to minimise the PV of *all* taxes paid on corporate income. The figure below shows what taxes can be paid.

Since there can be different rates of personal tax on equity than on interest, the relative tax advantage of debt is as follows:



$$\text{Relative tax advantage of debt} = \frac{1 - T_p}{(1 - T_{pE})(1 - T_c)}$$

If there is no difference between tax on equity and on interest, the tax advantage of corporate borrowing is exactly as MM calculated it. In case the income after all taxes of the bondholder is equal to that of the stockholder, debt policy irrelevancy is cancelled. Still, it seems money can be made by having more debt, which conflicts with MM's proposition 1. There has to be something more.

18.3 Costs of Financial Distress

Financial distress occurs when promises to creditors are broken or honoured with difficulty. It is reflected in the current market value of the firm's securities:

$$\text{Value of firm} = \text{value if all} - \text{equity} - \text{financed} + \text{PV(tax shield)} - \text{PV(costs of financial distress)}$$

The theoretical optimum is reached when the PV of tax savings due to further borrowing is just offset by increases in the PV of costs of distress. This is called the *trade-off theory* of capital structure.

Bankruptcy Costs

Corporate bankruptcies occur when stockholders exercise their **right to default**; when a firm gets into trouble, limited liability allows stockholders simply to walk away from it, leaving the troubles to the creditors. In case this happens, so when a firm does go bankrupt and its stockholders walk away, its bondholders become the new stockholders. The costs of changing these bondholders to stockholders are called **bankruptcy costs**.

Direct versus Indirect Costs of Bankruptcy

Next to *direct* (legal and administrative) costs of bankruptcy, there are also indirect costs, which are nearly impossible to measure.

Debt and Incentives

Stockholders are tempted to forsake the usual objective of maximising overall market value and to pursue narrower self-interest instead. They are tempted to play games at the expense of their creditors.

Risk Shifting: The First Game

This game is about setting up projects with way too much risk and even negative NPVs, only in the stockholders' favour. Stockholders of levered firms gain when business risk increases. Financial managers who act strictly in their shareholders' interests will favour risky projects over safe ones.

Refusing to Contribute Equity Capital: The Second Game

Sometimes stockholders will not contribute capital to even positive NPV projects, since project benefits must be shared with bondholders. If the company goes bankrupt anyway, they lose that capital.

And Three More Games, Briefly

- **Cash In and Run:** Stockholders coming in because dividends paid are higher than stock price.
- **Playing for Time:** Delaying the salvage of the creditors, in many different ways.
- **Bait and Switch:** Starting with a limited amount of relatively safe debt, then suddenly switch and issue a lot more, making all debt risky and imposing a capital loss on the 'old' bondholders.

What the Games Cost

Playing these game means poor decisions about investments and operations. These poor decisions are *agency costs* of borrowing. A lender (e.g. a bank) can restrict its debtors from selling assets or making major investment outlays except with the lenders' consent. This can also work counterproductive, for example when *good* investments are blocked.

Costs of Distress Vary with Type of Asset

Moral: Do not think only about the probability that borrowing will bring trouble. Think also of the value that may be lost if trouble comes.

18.4 The Pecking Order of Financing Choices

The pecking-order theory starts with **asymmetric information**; meaning that managers know more about their companies' prospect, risks and values than outsiders. It affects the choice between internal and external financing and between new issues of debt and equity. This leads to a **pecking order**, in which investment in financed first with internal funds, reinvested earnings primarily; then by new issues of debt and finally with new issues of equity.

Implications of the Pecking Order

The *pecking-order theory* of corporate financing goes like this:

1. Firms prefer internal finance.
2. Their target dividend pay-out ratios are adapted to their investment opportunities, while trying to avoid sudden changes in dividends.
3. Sticky dividend policies, plus unpredictable fluctuations in profitability and investment opportunities, mean that internally generated cash flow might be sometimes than capital expenditures and sometimes less. If more, the firm pays off debt or invests in marketable securities. If less, the firm first draws down its cash balance or sells marketable securities.
4. If external finance is required, firms issue the safest security first. So they start with debt, then possibly hybrid securities and perhaps equity as last resort.

The Trade-Off Theory vs. the Pecking-Order Theory – Some Evidence

Rajan and Zingales found that the debt ratios of individual companies depend on four main factors:

1. **Size:** Large firms tend to have higher debt ratios.
2. **Tangible assets:** Firms with high ratios of fixed assets to total assets have higher debt ratios.
3. **Profitability:** More profitable firms have lower debt ratios.
4. **Market to book:** Firms with higher ratios of market-to-book value have lower debt ratios.

Pecking order theory works best for large, mature firms.

The Bright Side and the Dark Side of Financial Slack

Financial slack means having cash, marketable securities, readily saleable real assets, and ready access to debt market or to bank financing. In other words, being at the top of the pecking order.

Is There a Theory of Optimal Capital Structure?

No.

Chapter 20 Understanding Options

20.1 Calls, Puts, and Shares

There are two types of options: **calls** and **put**.

Call Options and Position Diagrams

A **call option** gives its owner the right to buy stock at a specified *exercise* or *strike price* on or before a specified maturity date. If it can be exercised only at maturity, the call is known as a **European call**, else, it is an **American call**.

A position diagram shows the possible consequences of investing in a specific stock with a certain exercise price. It has the share price on the x-axis and value of put or call on the y-axis.

Put Options
Put options give you the right to sell stock. Its value at expiration is the exercise price minus the market price of the share:

$$\text{Value of put option at expiration} = \text{exercise price} - \text{market price of the share}$$

Selling Calls, Puts, and Shares
Sellers, or *writers*, of calls and puts are obliged to respectively deliver shares and buy shares at the exercise price.

Position Diagrams Are Not Profit Diagrams
Position diagrams show *only* the payoffs at option exercise. When one wants to know the profit, a *profit diagram* is drawn. It is basically the same, except for that profit is on the y-axis.

20.2 Financial Alchemy with Options
By combining purchasing/selling call and put options with buying shares, downside protection and other securities can be created. There is a fundamental relationship for European options:

$$\text{Value of call} + \text{present value of exercise price} = \text{value of put} + \text{share price}$$

This basic relationship among share price, call and put values, and the present value of the exercise price is called **put-call parity**. When the left side is smaller than the right side, one should buy calls and invest at the risk-free rate, and sell the put and stock short. At the other hand, when the left side is bigger, calls should be sold, there should be borrowed at the risk-free rate, and puts and shares should be bought.

Spotting the Option
Any set of contingent payoffs – that is, payoffs that depend on the value of some other asset – can be constructed with a mixture of simple options on that asset. This practice of packaging different investments to create new tailor-made instruments, is called **financial engineering**.

20.3 What Determines Option Values?
The image below summarises section 20.3.

TABLE 20.2 What the price of a call option depends on.

1. If there is an *increase* in:	The change in the call option price is:
Stock price (P)	Positive
Exercise price (EX)	Negative
Interest rate (r_f)	Positive*
Time to expiration (t)	Positive
Volatility of stock price (σ)	Positive*

2. Other properties of call options:

a. *Upper bound.* The option price is always less than the stock price.

b. *Lower bound.* The call price never falls below the payoff to immediate exercise ($P - EX$ or zero, whichever is larger).

c. If the stock is worthless, the call is worthless.

d. As the stock price becomes very large, the call price approaches the stock price less the present value of the exercise price.

*The direct effect of increases in r_f or σ on option price, *given* the stock price. There may also be *indirect* effects. For example, an increase in r_f could reduce stock price P. This in turn could affect option price.

Chapter 21 Valuing Options

21.1 A Simple Option-Valuation Model

Why Discounted Cash Flow Won't Work for Options

Options cannot be valued by discounting cash flows, because finding *the* OCC is impossible, since risk of an option changes every time the stock price moves.

Constructing Option Equivalents from Common Stocks and Borrowing

There are two to calculate the value of an option:

1. Find the combination of stock and loan that replicates an investment in the option. Since the two strategies give identical payoffs in the future, they must sell for the same price today.
2. Pretend that investors do not care about risk, so that the expected return on the stock is equal to the interest rate. Calculate the expected future value of the option in this hypothetical risk-neutral world and discount it at the risk-free interest rate.

For both ways, the solutions are given below.

Combination of stock and loan

An option can be valued by borrowing money and buying stock in such a way that exactly the payoff from a call option is replicated. This is called a **replicating portfolio**. The number of shares needed to replicate one call is called the **hedge ratio** or **option delta**. The formula for this option delta is:

$$\text{Option delta} = \frac{\text{spread of possible options prices}}{\text{spread of possible share prices}} = \frac{\text{highest option price} - \text{lowest option price}}{\text{highest share price} - \text{lowest share price}}$$

With this delta, the value of a call can be calculated:

$$\begin{aligned}\text{PV(option)} &= \text{value of } \mathit{delta} \text{ shares} - \text{PV(bank loan)} \\ &= \text{delta} * \text{current stock price} - \frac{\text{delta} * \text{lowest possible share price}}{(1+r)^t}\end{aligned}$$

Notice that this works for both call and put options.

Risk-Neutral Valuation

Another way to value an option is by pretending that all investors are indifferent about risk, work out the expected future value of the option, and discount it at the risk-free interest rate. If investors are indifferent to risk, the expected return must be equal to the risk-free rate of interest. Now, in case the stock price of a call option falls, the option will be worth nothing. Therefore, we must calculate only the probability that the stock will rise, multiply it by the increase in value, and discount it at the risk-free interest rate. In formulas:

$$\text{Probability of rise } \rho = \frac{\text{interest rate\%} - \text{downside change\%}}{\text{upside change\%} - \text{downside change\%}}$$

Then the current value of the option is:

$$\text{PV(option)} = \frac{\rho * \text{option worth when rise} + (1-\rho) * \text{option worth when drop}}{(1+\text{r})^t}$$

These solutions work for both call and put options. Notice that call options are worthless when stock prices drop, while put options are worthless when these prices rise.

21.2 The Binomial Method for Valuing Options

Another way of valuing options is called the **binomial method**. The method starts by reducing the possible changes in the next period's stock price to two, namely an 'up' move and a 'down move'. This process can be repeated infinitely. E.g., say that a stock price can only rise 25% each year, or drop 20%. This would not be a very accurate estimate. Now say it can rise or drop each half year, or every quarter of a year, that would be more accurate already. Working back from expiration time to the current time, in a certain amount of period, is the binomial method. The option value is the same as if risk-neutral valuation is used:

$$\text{PV(option at } t_i) = \frac{\left(\rho * \text{PV(option at } t_{i+1} \text{ when rise)} + (1-\rho) * \text{PV(option at } t_{i+1} \text{ when drop)}\right)}{(1+r)^t}$$

Hint: Look at pp. 542-543 of Brealey et al. for a clear explanation.

The General Binomial Method

Since the previous subsection was not so clear, these are the general formulas:

$$1 + \text{upside change} = u = e^{\sigma\sqrt{h}}$$

$$1 + \text{downside change} = d = 1/u$$

Where h is the interval as fraction of a year, and σ = ln(u)/$\sqrt{h}$

21.3 The Black-Scholes Formula

If the binomial method is repeated numerous times, the option's price becomes lognormal distributed. From that point, there is an even more precise way of valuing stock, namely the **BlackScholes formula**. It subdivides the option life into indefinitely small slices. That does not affect the principle of option valuation; the call option could still be replicated by a levered investment in the stock. Though, the degree of leverage would need to be adjusted continuously as time went by. The formula is as follows:

Value of call option $=$ delta $*$ share price $-$ bank loan $= N(d_1) * P - (N(d_2) * PV(EX))$ where

$$d_1 = \frac{\log\left(\frac{\mathrm{P}}{\mathrm{PV(EX)}}\right)}{\sigma\sqrt{t}} + \frac{\sigma\sqrt{t}}{2}$$

$$d_2 = d_1 - \sigma\sqrt{t}$$

$N(d) = \text{accumlated chance that of } d \text{ in normal distrubution; } \Phi(d)$

The Risk of an Option

As explained before, a call can be replicated exactly by a combination of risk-free borrowing and an investment in the stock. Therefore, the beta must be the same as the risk of this replicating portfolio. Beta of stock is usually given, and beta of a risk-free loan is of course 0. Calculating the option's beta is done as follows:

$$\beta_{\text{option}} = \text{loan} * \beta_{\text{loan}}(= 0) + (\text{Delta} * \text{price}) * \beta_{\text{stock}}$$

21.5 Option Values at a Glance

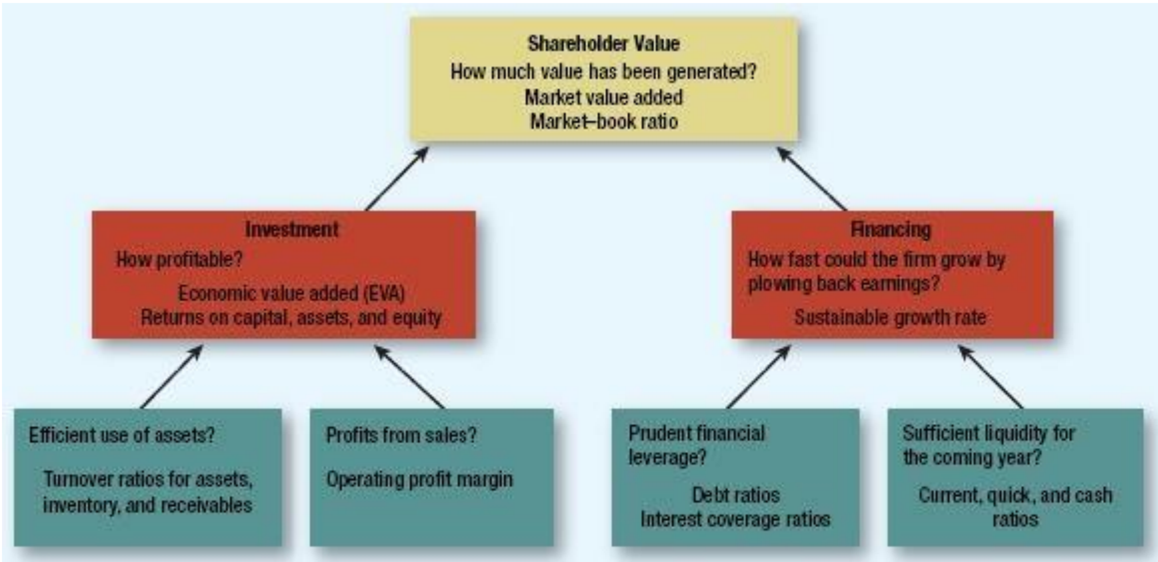
So far only option that are held until maturity and without dividends has been discussed. What happens with American stocks, and when stocks do pay dividends?

- **American Calls – No Dividends:** Since an American call should not be exercised before maturity, its value is the same as that of a European call, and the Black-Scholes model applies to both options.
- **European Puts – No Dividends:** Value of put = value of call – value of stock + PV(exercise price).
- **American Puts – No Dividends:** Sometimes it can be worth exercising a put option before maturity. Thus an American put is always more valuable than a European put. Because the Black-Scholes formula does not allow for early exercise, it cannot be used. Step-by-step binomial method can be used.
- **European Calls and Puts on Dividend-Paying Stocks:** Part of the share value comprises the present value of dividends, which the option holders does not get. Therefore, when using the Black-Scholes model to value a European option on a dividend-paying stock, the price of stock should be reduced by the PV of the dividends to be paid before maturity.
- **American Calls on Dividend-Paying Stocks:** Only usable method is the step-by-step binomial method. In this case you must check at each stage to see whether the option is more valuable if exercised just before the ex-dividend date than if held for at least one more period.

Chapter 28 Financial Analysis

28.1 Financial Ratios

The figure below summarises the investment and finance decisions. It serves as a road map for this chapter.



28.2 Financial Statements

Financial statements are filed quarterly (10-Q) and annually (10-K). There are many differences in the accounting rules of different countries.

28.3 Home Depot's Financial Statements

The Balance Sheet

A balance sheet provides a snapshot of the company's assets at the end of the year and the sources of money that was used to buy those assets. Current liabilities include debts that are due to be repaid within the next year and payables. The **net working capital** or **net current assets** roughly measures the company's potential reservoir of cash:

$$\text{Net working capital} = \text{current assets} - \text{current liabilities}$$

The Income Statement

An income statement shows how profitable a firm has been over the past year.

28.4 Measuring Home Depot's Performance

Market capitalisation or **market value** is simply the amount of stocks multiplied by the stock price. **Book value** is the value of equity as listed in the annual report. The difference between those two values is called the **market value added**. Besides, the ratio between those two is called the marketto-book ratio:

$$\text{Market} - \text{to} - \text{book ratio} = \frac{\text{market value of equity}}{\text{book value of equity}}$$

This number indicates how much value has been added for each dollar shareholders have invested.

Economic Value Added (EVA)

Income statement do not include the opportunity cost of capital. The profit after deducting all costs, including the OCC, is called the company's **economic value added** or **EVA**. In formula:

$$\text{EVA} = (\text{after} - \text{tax interest} + \text{net income}) - (\text{cost of capital} * \text{capital})$$

Or, in other words:

$$\text{EVA} = (\text{return on capital} - \text{cost of capital}) * \text{total capital}$$

Here, after-tax interest is 1-*tax* multiplied by the interest expense, and total capital is the **total longterm capital**, or **total capitalisation**, also known as the sum of long-term debt and shareholders' equity.

Accounting Rates of Return

Three common return measures are the return on capital (ROC), return on equity (ROE) and the return on assets (ROA). These are all known as *book rates of return*.

$$\text{ROC} = \frac{\text{after} - \text{tax interest} + \text{net income}}{\text{total capital}}$$

$$\text{ROE} = \frac{\text{net income}}{\text{equity}}$$

$$\text{ROA} = \frac{\text{after} - \text{tax interest} + \text{net income}}{\text{total assets}}$$

28.5 Measuring Efficiency

The **asset turnover ratio** shows how often a dollar of assets has been earned each year:

$$\text{Asset turnover} = \frac{\text{sales}}{\text{total assets at } \textbf{start of year}} \text{ or } \frac{\text{sales}}{\textbf{average} \text{ total assets}}$$

Inventory turnover is all about how long it takes before inventory is sold:

$$\text{Inventory turnover} = \frac{\text{cost of goods sold}}{\text{inventory at start of year}}$$

$$\text{Average days in inventory} = \frac{365}{\text{inventory turnover}} \text{ or } \frac{\text{inventory at start of year}}{\text{daily cost of goods sold}}$$

Receivables turnover measures the firm's sales as a proportion of its receivables:

$$\text{Receivables turnover} = \frac{\text{sales}}{\text{receivables at start of year}}$$

$$\text{Average collection period} = \frac{365}{\text{receivables turnover}} \text{ or } \frac{\text{receivables at start of year}}{\text{average daily sales}}$$

28.6 Analysing the Return on Assets: The Du Pont System

The **profit margin** measures how profitable sales are:

$$\text{Profit margin} = \frac{\text{net income}}{\text{sales}}$$

This definition can be misleading. When companies are partly financed by debt, a portion of the profits from sales must be paid as interest. Therefore, when calculating profit margin, it is useful to add back the debt interest to net income:

$$\text{Operating profit margin} = \frac{\text{after} - \text{tax interest} + \text{net income}}{\text{sales}}$$

The Du Pont System

The **Du Pont formula** breaks down the ROA formula as follows:

$$\text{Return on assets} = \frac{\text{sales}}{\text{assets}} * \frac{\text{after} - \text{tax interest} + \text{net income}}{\text{sales}}$$

28.7 Measuring Leverage

Because debt increases the returns to shareholders in good times and reduces them in bad times, it is said to create *financial leverage*. Financial leverage is usually measured by the ratio of long-term debt to total long-term capital:

$$\text{Long} - \text{term debt ratio} = \frac{\text{long} - \text{term debt}}{\text{long} - \text{term debt} + \text{equity}}$$

It is also measured by the debt-equity ratio:

$$\text{Long} - \text{term debt} - \text{equity ratio} = \frac{\text{long} - \text{term debt}}{\text{equity}}$$

Sometimes it may be preferable to widen the definition of debt to include *all* liabilities:

$$\text{Total debt ratio} = \frac{\text{total liabilities}}{\text{total assets}}$$

Another measure of financial leverage is the extent to which interest obligations are covered by earnings. **Interest coverage** is measured by the ratio of EBIT to interest payments:

$$\text{Times} - \text{interest} - \text{earned} = \frac{\text{EBIT}}{\text{interest payments}}$$

Cash coverage ratio tells us whether a company is generating enough cash to repay its debt:

$$\text{Cash coverage} = \frac{\text{EBIT} + \text{depreciation}}{\text{interest payments}}$$

Leverage and the Return on Equity

An extended version of the Du Pont formula shows which effect dominates at the ROE:

$$\text{ROE} = \frac{\text{assets}}{\text{equity}} * \frac{\text{sales}}{\text{assets}} * \frac{\text{after} - \text{tax interest} + \text{net income}}{\text{sales}} * \frac{\text{net income}}{\text{after} - \text{tax interest} + \text{net income}}$$

with 1: leverage ratio, 2: asset turnover, 3: operating profit margin, 4: ‘debt burden’.

28.8 Measuring Liquidity

Liquid assets are assets that can be converted into cash quickly and cheaply. The difference between current assets and current liabilities is known as **net working capital**. The net-working-capital-tototal-assets-ratio is as follows:

$$\text{Net} - \text{working} - \text{capital} - \text{to} - \text{total} - \text{assets ratio} = \frac{\text{net working capital}}{\text{total assets}}$$

The **current ratio** is just the ratio of current assets to current liabilities:

$$\text{Current ratio} = \frac{\text{current assets}}{\text{current liabilities}}$$

Quick (Acid-Test) Ratio excludes inventories and other less liquid components of current assets:

$$\text{Quick ratio} = \frac{\text{cash} + \text{marketable securities} + \text{receivables}}{\text{current liabilities}}$$

Cash ratio only holds the most liquid assets:

$$\text{Cash ratio} = \frac{\text{cash} + \text{marketable securities}}{\text{current liabilities}}$$

Important Quantitative Analyses Excluded from Formula Sheet

Chapter 2

Annuity factor: $AF_3 = DF_1 + DF_2 + DF_3 = AF_2 + DF_3$ etc.

$$\text{Effective annual rate} = (1 + \frac{r}{m})^m; m \text{ is amount of compounds per year}, r \text{ annual percentage rate}$$

Continuous compounding: If APR is *r*, then continuous compounding rate is ln(1+r)

Chapter 3

Yield to Maturity: $PV = \frac{1}{1+r} + \frac{1}{(1+r)^2} + \cdots + \frac{1}{(1+r)^t}$; solve for r (YTM)

$$\text{Duration} = \frac{1 * PV(C_1)}{PV} + \frac{2 * PV(C_2)}{PV} + \cdots + \frac{T * PV(C_T)}{PV}$$

$$\text{Volatility}(\%) = \frac{\text{duration}}{1 + \text{yield}}$$

Real cash flow: $1 + r_{real} = \frac{1+r_{nominal}}{1+r_{inflation}}$

Chapter 4

General stock price formula: $P_0 = \sum_{t=1}^{H} \frac{DIV_t}{(1+r)^t} + \frac{P_H}{(1+r)^H}$; where H is the final year

Calculating growth rate: $g = plowback\ ratio * ROE$

$$\text{Plowback ratio} = 1 - \text{payout ratio} = 1 - \frac{DIV}{EPS}; \frac{DIV}{EPS} \text{ is called ratio of dividends to } EPS$$

$$ROE = \frac{EPS}{\text{book equity per share}}\text{; also called ratio of } EPS \text{ to book equity}$$

Chapter 7

$$\text{Expected return} = \sum_{i=1}^{k} \rho_i * \tilde{r}_i$$

$$\text{Variance } \sigma^2 = \sum_{i=1}^{k} \rho_i * (\tilde{r}_i - r)^2$$

$$\text{Portfolio variance} = \frac{1}{N} * \text{average variance} + \left(1 - \frac{1}{N}\right) * \text{average covariance}$$

Chapter 8

Sharpe ratio (when borrowing money and spending on portfolio): $\text{Sharpe ratio} = \frac{r - r_f}{\sigma}$

Arbitrage pricing theory: Expected risk premium $r = r_f + b_1(r_{factor\ 1} - r_f) + b_2(r_{factor\ 2} - r_f) +$

Chapter 9

Certainty-equivalent cash flow: $PV = \frac{CEQ_t}{(1+r_f)^t}$

Chapter 17

Proposition 2: Return on equity increases with more leverage, but r_A stays the same, so:

$$r_D * \frac{D}{V} + r_E * \frac{E}{V} \text{ must stay the same, only returns on equity and debt can change, and } \frac{\mathrm{D}}{\mathrm{E}} \text{ ratio}$$

Chapter 18

$$\text{PV(tax shield)} = \frac{\text{corporate tax rate} * \text{interest payment}}{\text{expected return on debt}} = \frac{T_C r_D D}{r_D}\text{; with D amount borrowed}$$

$$\text{Relative tax advantage of debt} = \frac{1 - T_p}{(1 - T_{pE})(1 - T_c)}$$

Chapter 20

Put-call parity: $\text{Value of call} + \text{present value of exercise price} = \text{value of put} + \text{share price}$

Chapter 21

Replicating portfolio

$$\text{Option delta} = \frac{\text{spread of possible options prices}}{\text{spread of possible share prices}} = \frac{\text{highest option price} - \text{lowest option price}}{\text{highest share price} - \text{lowest share price}}$$

$$\begin{aligned}\text{PV(option)} &= \text{value of } \mathit{delta} \text{ shares} - \text{PV(bank loan)} \\ &= \text{delta} * \text{current stock price} - \frac{\text{delta} * \text{lowest possible share price}}{(1+r)^t}\end{aligned}$$

Risk-neutral valuation

$$\text{Probability of rise } \rho = \frac{\text{interest rate\%} - \text{downside change\%}}{\text{upside change\%} - \text{downside change\%}}$$

$$\text{PV(option)} = \frac{\rho * \text{option worth when rise} + (1-\rho) * \text{option worth when drop}}{(1+\text{r})^t}$$

Binomial method

$$\text{PV(option at } t_i) = \frac{\left(\rho * \text{PV(option at } t_{i+1} \text{ when rise)} + (1-\rho) * \text{PV(option at } t_{i+1} \text{ when drop)}\right)}{(1+r)^t}$$

$$1 + \text{upside change} = u = e^{\sigma\sqrt{h}}$$
$$1 + \text{downside change} = d = 1/u$$

where *h* is the interval as fraction of a year, and σ = ln(u)/$\sqrt{h}$

Black-Scholes formula

$$\text{Value of call option} = \text{delta} * \text{share price} - \text{bank loan} = N(d_1) * P - \left(N(d_2) * PV(EX)\right)$$

where

$$d_1 = \frac{\log\left(\frac{\text{P}}{\text{PV(EX)}}\right)}{\sigma\sqrt{t}} + \frac{\sigma\sqrt{t}}{2}$$

$$d_2 = d_1 - \sigma\sqrt{t}$$
$$N(d) = \text{accumlated chance of } d \text{ in normal distrubution; } \Phi(d)$$

Risk of an option

$$\beta_{\text{option}} = \text{loan} * \beta_{\text{loan}}(=0) + (\text{Delta} * \text{price}) * \beta_{\text{stock}}$$

Chapter 28

$$\text{Net working capital} = \text{current assets} - \text{current liabilities}$$

Performance

$$\text{Market} - \text{to} - \text{book ratio} = \frac{\text{market value of equity}}{\text{book value of equity}}$$

$$\text{EVA} = (\text{after} - \text{tax interest} + \text{net income}) - (\text{cost of capital} * \text{capital})$$

$$\text{After} - \text{tax interest} = (1 - \text{taxrate}) * \text{interest expenses}$$

$$\text{Total capitalisation} = \text{long} - \text{term debt} + \text{shareholders' equity}$$

Efficiency

$$\text{Inventory turnover} = \frac{\text{cost of goods sold}}{\text{inventory at start of year}}$$

$$\text{Average days in inventory} = \frac{365}{\text{inventory turnover}} \text{ or } \frac{\text{inventory at start of year}}{\text{daily cost of goods sold}}$$

$$\text{Receivables turnover} = \frac{\text{sales}}{\text{receivables at start of year}}$$

Leverage

$$\text{Times} - \text{interest} - \text{earned} = \frac{\text{EBIT}}{\text{interest payments}}$$

An extended version of the Du Pont formula shows which effect dominates at the ROE:

$$\text{ROE} = \frac{\text{assets}}{\text{equity}} * \frac{\text{sales}}{\text{assets}} * \frac{\text{after} - \text{tax interest} + \text{net income}}{\text{sales}} * \frac{\text{net income}}{\text{after} - \text{tax interest} + \text{net income}}$$

with 1: leverage ratio, 2: asset turnover, 3: operating profit margin, 4: ‘debt burden’

Summary 2: Research Methodology

Chapter 5:

Research Methods

best practice
systematically and transparently address questions
must state transparently how you rationalize towards solutions

Core Problem

observe what is going on
problem statement & dependent variable & independent variable

Problem Statement

how to achieve

Research Questions and Sub Questions

similar questions follow the same pattern
(e.g) how can we decrease the customers' waiting time from 5 minutes to 2 minutes?
→ DV = waiting time (you want to change it → influenced → dependent), minutes influence waiting time
sub questions should be asked based on the consequence of RQ

Researcher

must explain why he chooses a particular research design

Research Design

general plan to answer research question
should be based on research questions and objectives
should be consistent
displays sources of what/how data will be collected
importance of clearly defining research question should not be over emphasized

Mediating Variable

middle of IV&DV
links IV and DV
explains how IV and DV are related
RQ: IV&MV → DV?

Moderating Variable

affects or changes the relationship between IV and DV
(e.g) age→ If all people tend to scan longer, age becomes moderating variable (longer scanning time, older age)
RQ: IV&MV -> DV?

Control Variable

held constant in research
controlled because it can influence outcomes
filter out CV → interested in the effect of IV on DV while filtering out the effect of CV
(e.g) some group performs well than other groups → depends on teachers so figure out by letting them to take the same test
RQ: IV-CV → DV

Research Paradigms: how to measure CV/IV/MV/DV?

Qualitative

draws conclusions from non-numerical and statistical data
(e.g) interview, observation, journals
use inductive or deductive approach
associated with action research
researchers are not considered to be independent from those being researched

depends on interpretation

Quantitative

draws conclusions from numerical and statistical data
(e.g) questionnaire, graphs, statistics
use deductive approach
Harking happens when the research is poorly designing → hypothesize after we know the result

Multiple method

choose both qualitative and quantitative
use more than one qualitative data collection technique

Multi and Mono method

choose qualitative or quantitative
use inductive approach or deductive approach or both
use more than one data collection technique for Multi, single data collection for Mono

- (e.g) questionnaire and structured observations → both are quantitative

Embedded mixed method research

- one method supports the other

Mixed methods

- uses both qualitative or quantitative

Concurrent: both qualitative and quantitative at the same time (parallel) → can

be concurrent embedded (e.g) survey and interview
Sequential exploratory: first qualitative, second quantitative (e.g) first interview,

second survey
Sequential explanatory: first quantitative, second qualitative (e.g) first survey and second interview
Sequential multi-phased: Qualitative → Quantitative → Qualitative (e.g) interview (test it) → questionnaire (again) → discuss based on questionnaire (test it)

Studies

Exploratory study:

explore the topic

- investigate a problem that is not clearly defined ○

determine casual relationships between variables ○(e.g)
discover what the topic is about

Explanatory study:explain the relationship between variables

- discover details for a problem that was not well researched before

Descriptive study:

- describe accurate patterns of events, people or situations

describe a phenomenon and its characteristics information is collected without changing the environment

used to quantify a single variable but not multiple variables

Evaluative study:

evaluate a product or concept

assess a project or goal

Combined studies

Research Strategy

plan of approach to achieve a certain goal

Research Strategies

Experiment:

study the probability of change in dependent variable when independent variable changes

Null hypothesis:

- there is no relationship between set IV and DV, accepted when statistical difference is greater than prescribed value

Alternative hypothesis:

- predicts there is a relationship

Classical experiment:

- people are randomly assigned to control or experimental group
- control group is influenced by the same external influences and experimental group changes to dependent variable

Quasi-experiment:

people are not randomly assigned

Survey:

deductive research

often exploratory and descriptive research

easy for people to understand and explain

make sure that sample is representative to whole population

Archival research:

uses historical and recent data documents

- research questions focused on past can be answered

Case study:

- can explore in real-life contexts

no clear boundary between topic and case

- useful when you want to gain better understanding of research or explore existing theory
- multiple data collection techniques used to ensure the validity of result →
- multiple cases → finding can be replicated
  - Holistic vs embedded:
    - Holistics → organisation as whole
    - Embedded → organisation as sub-units, involve more than one unit

Ethnography:

- studies particular groups
  - Realistic Ethnography:
    - objective, identify true meanings
    - people are observed through facts
  - Interpretive Ethnography:
    - subjective
    - people are treated like people → observation of participation
    - believes multiple meanings exist
- Critical Ethnography:
  - explores the impact of privilege, power and authority

Action research:

- interactive process to develop solutions to real organisations problems → allthe same circle
- use participative and collaborative approach
- Purpose: promote organizational learning to produce pratical outcomes
- Process: starts with particular context research question
- Participation: essential part
- Knowledge: different forms of knowledge
- Implications: participants will raise their expectations, research could usethe results to develop theory

Grounded Theory:

- developed using inductive approach
- theory is grounded in actual data
- hypothesis is developed after the data collection
- analyse meanings that social actors to make sense of their daily experiences in particular situations
- memo writing helps and created through the research
  - 3 stages
    - Open coding: reorganize data into smaller categories
    - Axial coding: determine relationships between categories
    - Selective coding: integration of categories to produce theory
    - Focused coding: data into categories
    - Two main stages: Initial and focused coding
- researcher is constantly comparing each item during all stages of coding

Narrative inquiry:

- participant is the narrator of story
- reader can find it easier to understand because researcher can provide his interpretation

Time Horizons

Cross-sectional:

- snapshot of data at certain time

describes incidence of phenomenon
explains how factors are related in different organisations

- use qualitative or mixed methods
  - (e.g) IT skills possessed by managers in one organization at given time
  (e.g) Relationship between expenditure on customer care training for sales assistants and sales revenue

Longitudinal:

diary that represent events over a specific period
time constraints can be used
(e.g) progress of people every 7 years of their life since 1964

Choosing a Subject for a Research Project

need to consider the ethics
some topics have more ethical difficulties
ensure that ethical issues will not be disadvantageous to participants
participants need to be aware of that they are subject of research

Quality of Research

to ensure quality in any scientific research one needs to consider the ‘canons of scientific inquiry’:

- Reliability:
  - reproducible
  - data collection techniques and analytic procedures would produce the same findings if they were repeated by someone else or another time
  - needs to work in a structured and methodological way

Construct validity:

- measured what the researcher intended them to assess ○

Internal validity:

- research displays a causal relationship between two variables ○

External validity:

- how well the research findings can be generalized
- how well the outcome can be applied to other settings
- researcher can find the same in other relevant settings or groups

Alternative Criteria to Assess Quality of Research:

Canons of scientific inquiry: suitable with quantative, positivist methods Researchers who undertake a qualitative research may find it difficult cover ‘canons ofscientific inquiry’ → new set of criteria named ‘authenticity criteria’

5.9 The role of the researcher

Role of researcher

External researcher:

full-time students usually adopt the role

- needs to identify an organization → researcher is external to the organisation
- needs to negotiate with its members to be able to access the organisationand to collect its data

Internal/practitioner researcher:

- works in organization
  easy access to the organisation
  have knowledge of the organisation
  understands the complexity of what is happening in that organization → can be disadvantage since the external researcher's assumptions can be different from reality

Chapter 3:

Literature Review

review that a person makes reasoned judgements about value of pieces of literature

review should be a funnel → narrowing down

Critical Literature Review

generates foundation that research is based
critically develops a transparent argument what the literature tells you abouta research question
evaluate what is or is not significant to research
must appear in project report
must include evaluation of research
present key points in structured way and show the relationship with the research
should not summarise
link different ideas to form a coherent and cohesive argument
you must:

- include the key academic theories
- show your knowledge is up to date
- use clear references to validate your words

structure of your review:

- one single chapter
  multiple chapters
  throughout your search

Deductive Approach

develop theoretical/conceptual framework first and then validate it using data

Inductive approach

analyze the collected data first and then develop the theoretical framework

Forms of Critical Review

Integrative review:

- generate new perspectives on topic or reveal unclear area
- most common for students

Theoretical review:

- examines body of theory
- establish what theories exist and relationships between them
- reveal lack of appropriate theories

Historical review:

- examines evolution of research on a specific topic over a period of time

Methodological review:

- focuses on research approaches
  provide framework for understanding methods
  enable researchers to draw on a wide body of methodological knowledge

Systematic review:

  use comprehensive pre-planned strategy to allow conclusions reach what is known

Three Ways of Using Literature

initial stage to form research proposal
to provide the theoretical framework and context
to place the research findings in the wider context of knowledge

Evaluating Literature

Relevancy: is the literature relevant to the topic?
Value: how “good” the literature is → research quality
Sufifency: have you read enough on the topic?

Literature sources

Primary/Grey literature:

  first occurrence of a piece of work
  public sources as reports and documents, but also unpublished work such as letters and memo’s
  not commercially published

- very detailed, but not easy to access → called as ‘grey literature’
- (e.g) government reports, 안네의 일기

Secondary literature

- formally published
- aimed at wider audience
- easier to locate
- better covered by tertiary literature
- (e.g) journals, books, IEEE
- Referenced academic journals → published articles are peer reviewed
- Professional and Trade journals, Newspapers → internal magazines, not peer reviewed and scientific but could be good for topics

Tertiary literature

- include online search tools, databases, and dictionaries (e.g) Find UT
- locate primary and secondary literature → called as ‘search tools’

Journals

- published on regular basis
- essential literature source for any research
- easy to access online

Refereed academic journals

- peer reviewed articles
- characterised by quality and suitability
- most useful for all

Professional journals

- made for their members (e.g) MIT Sloan
- more practical than academic journals

- usually not scientific but could be good for topics insights but caution

Non-academic journals

- have editors with subject knowledge
- varies so biased

Trade journals

- aimed at particular industries
- published by trade organisations
- insights but caution

Books

- books and monographs are written for specific audiences
- some are aimed at academic market

Newspapers

- good source of topical events
- sometimes review recent research reports

Reports

- difficult to gain access since some of them are not free

Conference proceedings

- some specific, some wide

Theses

- difficult to gain

Search Strategy should Include

- parameters
- key words and search terms
- databases and search engines that you will use
- criteria to select relevant and useful studies

Search terms

- keywords used to search for literature
- identifying them is key for successful searching
- Techniques for generating the search term:
  - discussion
  - reading initial articles on the topic
    - Search on Google with 'define: (enter term)'
  - Brainstorming
    - Relevance tree → hierarchical 'graph like'. Top level is the research question. Next level is two or more relevant subject areas. You subdivide as much as possible. Then identify the most relevant areas in the bottom of the tree. Important areas have more branches

Search Engines

- Google:
  - must be careful because research project should use academic sources
- Stemming:
  - removes word's endings
  - meaning of the word changes
  - (e.g) Caring → Car
- Lemmatization:

- removes spelling differences between UK and US English
- keeps the context and meaning of the word
- (e.g) Caring → Care

Boolean operators:

- AND, OR, NOT, * (wild card)
- (e.g) Google * I love you → text should contain Google <anything> and I love you

Skills for Effective Reading

Previewing:

- browsing the text to find out what its purpose

Annotating:

- conducting an analogue with yourself, the author and the issues at stake

Summarising:

- can explain the text in your own words

Comparing and contrasting:

- how has your thinking been altered by this reading?Use

review questions:

- questions which you ask yourself during reading which are linked to your research questions

When Recording the Literature Make Notes

Bibliographical details
Summary of the content
Supplementary information

Systematic Review

review the literature using comprehensive pre-planned strategy
conclude what is known and what is not known

Micro Lectures:

Modes of Searching

Known item search

- find the full text of publication

Following a thread

- finding articles with a lineage relation
  - backward via references
  - forward via citations
- finding similar articles
  - corresponding references
  - corresponding authors
  - corresponding keywords

Systematic search

Why Systematic Search?

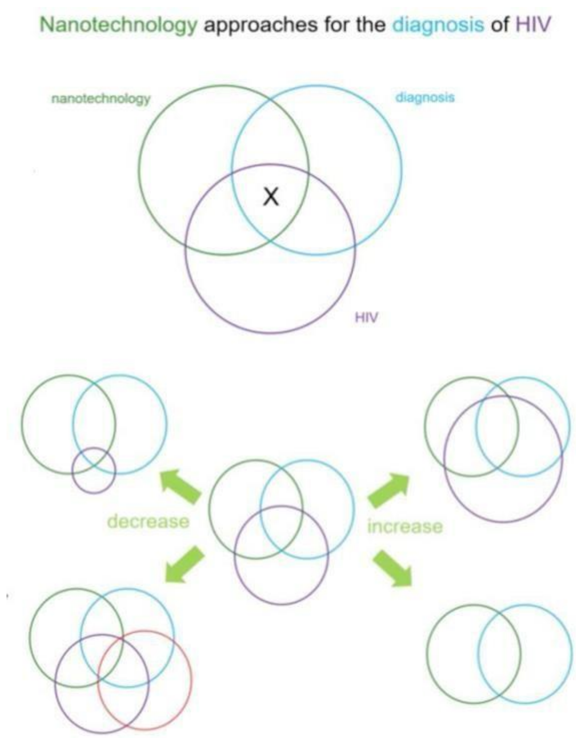
to study assignments, extra time, a lot of effort

no need to reinvent or start from scratch better
results, better sources
get all results for research topic
to clarify your research question: what is already known
to know your field: authors, methods, theories
how to interpret new results in the light of prior research? -> complete overview
process of searching is iterative

Systematic Search

Problem statement: define the problem
Criteria: what kind of scientific literature do I need for the problem?
Choice of databases
Search terms: (search results: title, abstract, keywords)
Search techniques
Search: search in database
Evaluation
Document: zoom your problem statement, whole cycle can be done again

Search Terms



Proximity Operators

loosen up your phrase search
flexibility in order and number of words (n) in between two terms:

	Scopus	Web of Science
Distance specified	W/n	NEAR/n

Distance and order specified	PRE/n	

Boolean Operators

Parenthesis " " used to find the exact term

HIV OR AIDS OR "corona virus" OR lentivirus

Truncation * used to find nanotechnology, nanotechinics at the same time

nanotechn* OR nanomaterial OR nanostructur*

Masking ? was used to indicate that only one single letter can be changed as z and s

sensing OR recogni?e

Wildcards for Different Bibliographical Databases

Number of characters	Scopus	Web of Science	EBSCOhost
0 or more (any)	*	*	*
0 or 1 (zero or one)		$	$
1 (single character)	?	?	?
Singular or plural	Yes	Yes	Not always
Spelling varations	Yes	Yes	Not always

Iterative Modifying your Search to Get Better Results

Too much	Too little	Noise
AND	OR	NOT → but you may exclude relevant information of your search
Add terms	Delete terms	AND
Restrict advanced search options (e.g) only search for title words	Proximity search	Use phrase searching: "human immunodeficiency virus" → use specific terms that you want to search
Use refine options → filtering	Wildcards → search different variations of your search terms	Ranking results → get relevant results on top

Evaluation

CRAAP Test

- Currency: how actual is this information?, varies between research topics/disciplines
- Relevancy: how relevant is this source for my research question?, content/level/language
- Authority: who wrote it, where does this information come from?, expertise/reputation

Accuracy: how reliable and valid is this information?, peer reviewed/prestige of

the journal
Purpose: With what purpose was this information shared?, scientific or professional?

Document your Search

reflect on your search process
looking back at your actions, how could you improve your search? ○ any notable patterns

- recurring journals?
- experienced authors?
- found any valuable keywords?
- log your process and progress

Date	Database	Search sentence (used tools or ranking)	#hits	Findings
2/1	Scopus	(nanotechnology OR nanoparticle) AND (diagonosis) relevance ranking	>17,000	Not many relevant. Add extra key concept: HIV. New terms: detection, “lab on a chip” Truncate diagnosis to diagonos*

When do you Stop Searching?

depends on your aim
(e.g) number of citations, how many publications can you handle?
balance between two measures → rule of thumb

precision: percentage of records in your search result that you consider asrelevant regarding your search topic
(e.g) work with a sample of the first 30 records in your search result

- recall: inclusion of all key papers in your search result
(e.g) identify key papers you consider very relevant for your search topic during your searches, monitor in your follow up searches whether you have these key papers in your search result

strive for high precision with complete recall

Scopus

bibliographic database
coverage
searches in bibliographic fields

Mendeley

reference management software personal database with references metadata of references (records) in fieldsattachment of pdfs → annotations

in text citations and creation of reference lists
desk top and web version → synchronization
can be integrated with MS Word

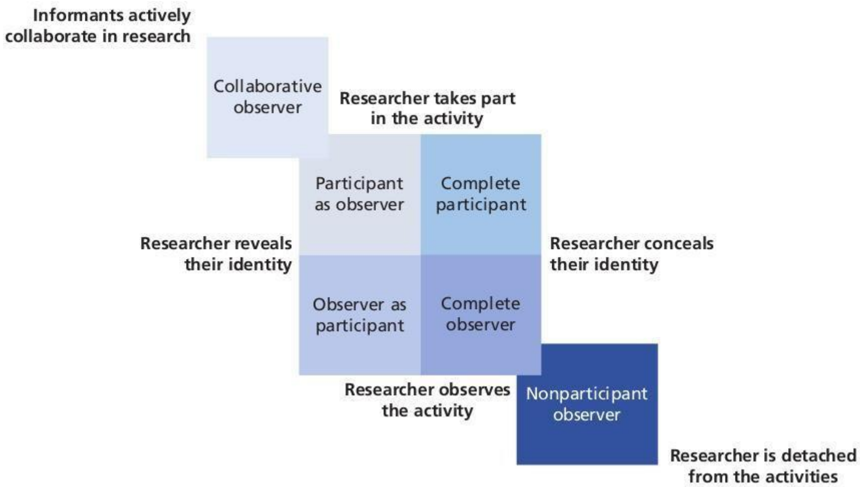
Chapter 9:

Observational Studies

mostly done by qualitative approach
(e.g) video data, audio data, pictures, notes
(e.g) how can you measure culture?, how/what will you observe?

Observation

involves the systematic observation, recording, description, analysis and interpretation of people’s behavior
traditionally neglected method
technology helped to facilitate new forms of observation



Participant Observation

Complete Participant
- research becomes a member of the group
- researcher doesn’t reveal the purpose to the members

Complete Observer
- researcher does not reveal the purpose of the activity to the members
- researcher does not participate in the activities

Observer as Participant
- research only observes and does not participate in the activities of the group
- researcher reveals his purpose

Participant as Observer
- researcher participate in the activities of the group
- researcher reveals his purpose

Collaborative Observer
- seeks to overcome potential ethical concerns and data quality issues

- you would not assume a dominant role

Non-participant Observer

- researcher does not share any physical or virtual proximity to people that they observe
  (e.g) researcher uses internet to observe material online

Types of Observation

Overt Observation

- researcher reveals his purpose

Covert Observation

- researcher conceals his purpose

Types of Participation

Moderate Participation

limited level of involvement

Active Participation

observe (outsider) and interact (insider)

Bias

Observer Error:

misinterpretation of situation

- (e.g) not many yellow cars today so there are not many yellow cars -> you observe many yellow cars tomorrow so you overestimated

Observer Drift

- inconsistency in how you label observations
- (e.g) you change it to ‘gold’ for yellow cars but they call it yellow cars in historical data

Observer Bias

- subjective interpretation of the situation

Observer Effect

- change behaviour due to observer
  (e.g) change the lightening to check if it affects working behaviour and change the light colour based on the observation

Data

Primary observations:

- data that explain what happened or what was said at the time (e.g) diary

Secondary data:

- statements by observers of what happened or what was said
- involves interpretations.

Experiential data:

- data on perceptions and feelings as the researcher experiences the processhe is researching

Contextual data:

- data related to the research setting.

Structured Observation

data is collected systematically to describe accurately
quantitative
Data quality

Time error → data taken in rush hours etc

- Information error → data are unreliable

Internet-mediated observation

online research

Bales' Interaction Process Analysis

to check how people interact and communicate each other
remove a lot of bias
structured, coding
coders identify every act of every group member

Chapter 10:

Research Interview

conversation between two or more people with purpose
require interviewer to make a rapport, ask concise and unambiguous questionsto willing to respond, and listen attentively
gather valid and reliable data that are relevant to research question and objectives
can help to refine your ideas
general term for several types of interview

Objective Approach

research interview to collect data from interviewees who are treated as witnesses to a reality that exists independently
historical roots in research
only seeks answers rather than trying to understand

Subjective Approach

data is socially constructed
linked to perspective of social world
recognises the central role of the interviewer

Structured Interviews

conducted using researcher-completed questionnaires
standardised questionnaires based on predetermined identical questions
read questions exactly to avoid bias
response on standardized schedule with pre-coded answers
used to collect quantifiable data
referred as quantitative research interviews
helpful in descriptive study

Semi Structured Interviews

start with predetermined list of themes that depends on your philosophical assumptions and key questions related to the themes
does not use them in a structured way
researcher may use some questions in some interviews and other questions

in others
non-standardised
referred as qualitative research interviews helpful
in explanatory study and evaluative study

In Depth (Unstructured) Interviews

informal
explore a general area that you are interested in
do not use predetermined themes or questions
find out themes emerge from the data you collect from your participants
helpful in exploratory study
narrative interview:

explore a topic

- deconstruct and understanding meanings to generate stories

biographical interview:

- record a life history to focus on participants' perceptions

informant interview:

- interviewee is free to talk about events, behaviour and beliefs
- interviewee guides the interview

respondent interview:

- interviewer has greater control over the direction of the interview
- allow the interviewee's opinions to emerge

Dialogic Interview

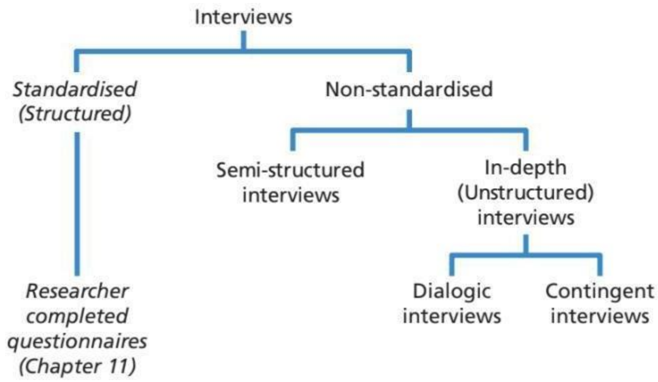
interviewer works to establish rapport with the interviewee to gain her trust
important to spend a lot of time to gain trust
focused on what has been observed or experienced

(e.g) to understand how meanings are socially constructed

Convergent Interview

same as in depth(unstructured) interview and informant interview in the beginning andmore specific questions like subsequent interview, respondent interview later

more specific and focused on testing emerging theory or refine a developing explanation that is grounded in the data generated through the initial exploratory interview stage
more than just a way to conduct interview → package or process
stresses the importance of the interactive relationship between data collection and analysis
quick method to converge on key aspects in emergent research project



One-to-One Interview

between you and a single participant
(e.g) face-to-face, telephone, internet

One-to-Many Interview

between you and a group of people
(e.g) face to face, internet interview

Two-to-Many Interview

two interviewers conduct interview
1 interviewer leads the discussion and another interviewer acts as a note taker

Face-to-Face Interview

meet your participant in person
meet and build rapport
encourages open discussion, rich data, free from bias

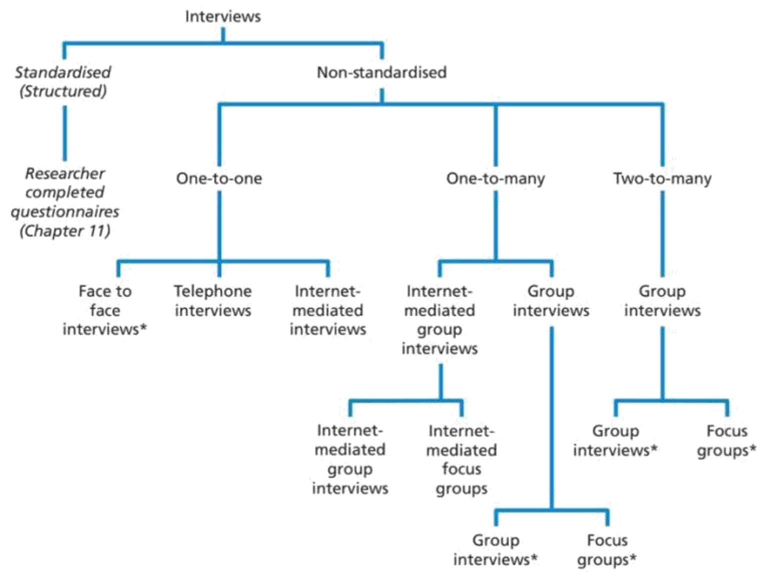
Group Interviews

number of participants take part as one-to-many or two-to-many
group interview and focus group are interchangeable (can be replaced) but should be avoided due to different purposes

Visual Interview

used in face-to-face interviews and in some group interviews

Each type of research interview has a distinct purpose



Use of Semi-Structured and In-Depth Interviews may be Advantageous

used to gather data and do qualitative analysis (e.g) case study
Purpose of the research:

- included for exploratory or explanatory research
- let the interviewees explain their responses

Significance of establishing personal contact:

- sometimes participants wish to reflect on events without needing towrite anything down (as with filling out a questionnaire)

Nature of questions:

- most advantageous for a large number of questions to be answered
- complex or open-ended questions, where order and logic of questioning varies

Length of time required and the process' completeness

- negotiation is always possible
  interview can take place at a time that satisfies the interviewee

Data Qualitative Issues with Semi-Structured and In-Depth Interviews

reliability, bias, generalizability and validity issues
lack of standardisation leads to reliability → not feasible to overcome this issue, it will always present.
always flexible because different questions were used with different participants

Bias

Interviewer bias:
comments, tone or non-verbal behaviour of the interviewer
Interviewee/response bias:
caused by perceptions about the interviewer
feeling forced to answer in a certain way
Participation bias:
results from the nature of the participants
interview can be time-consuming so participants become tired and less willing to talk

all participants are from certain company

Data Quality Issues

Reliability/dependability:

findings that are derived from using in-depth or semi structured interviews are not repeatable

Cultural reflexivity and participatory research:

participants from different culture in cross national or multicultural setting

Generalizability/transferability:

results of a research are applicable to other settings

issue with semi-structured and in-depth(unstructured) interview because they are based on samples.

Validity/credibility:

in-depth or semi structured interviews can achieve high level of validity/credibility

refers to the researcher succeeded in gaining access to a participant's knowledge and experience and can infer meanings that the participant intended

Preparing for Semi-Structured and In-Depth Interviews

consider 'five Ps' (purpose, principles, processes, people, performance)

prior planning prevents poor performance

should consider some key measures to prepare for the interviews to avoid data quality issues when conducting in-depth or semi-structured interviews

Level of knowledge:

researcher should always be familiar with the research topic and environment that the interview will take place

interviewing participants from different cultures requires the interviewer to gain some knowledge about the cultures

Developing interview themes and providing the interviewee with information before the interview

let interviewees to prepare themselves for the interview

Appropriateness of the intended interview location

location that interviews will be conducted can influence the data he collects

location should be convenient for the participants and comfortable

Appropriateness of the Researcher's Appearance

interviewer's appearance may affect the perception of the interviewee

can have an effect on his/her credibility or result in a failure to gain their confidence

Nature of the First Comments When the Interview Starts

if the interviewee has never met the interviewer, the first few minutes of conversation will have a large impact on the outcome of the interview

related to the issues of credibility and the interviewee's confidence

Approach to Questioning

questions need to be phrased clearly

interviewer should have a neutral tone of voice

open questions should help to avoid bias questions that are seeking to lead the interviewee should be avoided

critical incident technique:

- participants are asked to give detailed description relevant to the research question

Appropriate use of Different Types of Questions

Open questions*:*

- allow interviewees to define and describe a situation or event

Specific/Closed questions:

- used as opening questions when one begins questioning about a particular interview theme

Probing questions:

- can be used to provide for further exploration of an interviewee's response
- used to dive deeper into the research topic

Scope to Summarise and Testing Understanding

interviewee may test his understanding by summarising an explanation given by the interviewee

Dealing with Difficult Participants

always remain polite and do not show irritation

Approach to Recording Data

beneficial to audio-record an interview and make notes

interviewers immediate impression of how well the interview went

interviewer should always note contextual data:

- location of the interview
- date and time
- setting (noisy, interrupted)
- background information about participant

Group interviews of In-Depth or Semi-Structured Interviews

conducted with two or more people

be aware that a few interviewees could dominate the discussion while others may feel inhibited

Group interviews:

- general term to describe all semi structured and in-depth interviews conducted with two or more interviewees
- once a sample has been selected, participants should be grouped

Focus group interviews:

- focused on particular issue
- topic is defined clearly and precisely
- purpose is named the 'moderator' or 'facilitator' because he needs to keep the group within the boundaries of the topic being discussed and generate interest in the topic and encourage discussion.

helpful to make groups that participants have a similar status and similar work experiences

researcher should seek to reduce the contributions of people who tend to dominate the discussion

When conducting many group interviews and the fourth or fifth group interview is no longer providing the researcher with new information, he has reached saturation

Telephone Interview

low cost
easier access
fast speed
may be the only possible option because of long-distance
issues of reduced reliability → participants less willing to engage in exploratory discussion
interviewer is not allowed to witness the non-verbal behaviour of his interviewee

Internet and Intranet-Mediated Interviews

both in real time(synchronous) and offline (asynchronous)
offline(asynchronous) interviews could be held using emails or internet forums
(e.g) chat room interviews or Voice-over Internet Protocol interview (such as Skype)

Chapter 13:

Tips for Qualitative Analysis

Intermit summaries: made during analysis, outline of what you found
Transcript summaries: compress long statements to short key elements
Document summary: list few key points
Self-memos: record ideas that occurred during the analysis
Research notebook: alternative to record ideas about research
Reflective diary: researcher writes self-reflection about the analysis

Approaches to Analysis

Categorising: divide data into categories
Unitising data: units of data are attached to appropriate categories
Developing testable proposition: existence of relationship needs to be tested → create testable preposition → can be done by seeking alternative explanations/negative explanations
Drawing conclusion: interpret and analyse the data

Concurrent Process of Analysis

Data reduction: summarise and simplify collected data
Data display: organize and assemble data into summary diagrams or visual displays extended text -> all data that is not summarized or reduced
Drawing conclusions: allow the researcher to make comparisons between data

Analytical Procedures

Inductive procedure:

use ground Theory Method -> see chapter 5
- template analysis
  - List of codes/categories for themes discovered in the data
  - permits prior theory/specification
  - less structured
  - enable research to display codes hierachically
- Analytic induction
  - process of collecting and analysing to establish causes of particular phenomenon
  - repeated cycles
  - focuses more on existing knowledge
- Narrative Analysis
  - data is collected through experiences of participants
  - cannot be easily broken down (fragmented) into smaller pieces
  - need to be left intact or restoried
- Discourse analysis
  - covers wide approaches
  - analysis of language

Deductive
- pattern matching
  - predicting result based on preposition
  - researcher need to develop conceptual framework using existing theory and test it
- explanation building
  - build explanation by collecting data
  - similar to GTM but starts with prepositions and validates it

Different Kinds of Coding to Analyse the Data

Initial or open coding: disaggregate of data into smaller units
Focused coding: reanalyse the data to test initial codes that may be used to categorise larger units of data
Axial coding: process of discovering relationships between categories
Labelled selective coding: integrate categories around a core category to generate a theory

Chapter 8:

Secondary Data

subsequently stored includes text and numbered data
may not be authentic reliable
data already collected for purposes
include publsihed summaries, raw data -> include both qualitative and quantitative data
Three main types of secondary data: survey, doc, multiple sources
most require combination of primary and secondary data
usually less recent
once located, you must assess secondary data sources to ensure their overall suitability for your research question(s) and objectives. In particular, you need to pay attention to the measurement validity and coverage of the data

Raw Data

data that secondary data analysed further hasn’t processed

Compiled Data

received some form of selection or summarizing
can be analysed further

Structured Data

organized into format that is easy to process (e.g) database, spread sheet

Unstructured Data

not easy to search
do not follow predefined structure

Big Data

data in massive volume, complex on variety

Three Main Subgroups of Secondary Data

Survey-based secondary data:

collected for some other goal using survey strategy
usually questionnaires
available through compiled data tables or downloadable matrix of raw data can be collected by censuses (participation is obligatory), continuous/regular surveys (censuses repeated over time) or ad hoc surveys (specific in their subject matter)
Ad hoc Surveys:

usually one-off surveys

far more specific in their subject matter

include data from questionnaires that undertaken by independent researchers with interviews undertaken by organisations and governments

can gain access to use raw data

Documentary secondary data:

used in research projects that collect primary data
include texts (e.g) books, journals, magazine articles, administrative and public records

Multiple sources secondary data:

compiled entirely from documentary or survey secondary data or both different data sets combined to form a new data set prior to assess the data ○
can be compiled by extracting and combining particular variables from surveys to provide ’longitudinal data’

Longitudinal data: one or more comparable variables, surveys to combinecan be compiled for the same population over a period of time using series ofsnapshots to form ‘cohort studies’

Cohort studies: studies are relatively rare, the vs from big data is about

Advantages of Secondary Data

fewer resource requirements
saves time and money less obstructive to use
longitudinal studies may be feasible: creating own or use existing multiple
source dataset can result in unforeseen discoveries and new insights
can provide comparative and contextual data
permanence of data

Disadvantage of Secondary Data

data might not be suitable
more difficult and expensive access
aggregations and definitions may be unsuitable
no control of data quality
initial purpose may affect how data are presented

When Using Secondary Data

ensure that data enables to answer the research questions and meet objectivespossible
to gain access to the data when benefits of the data > costs

Measurement bias Occur for Three Reasons

deliberate distortion of data:
- occurs when data are recorded inaccurately on purpose
- most common for secondary data sources (e.g) organizational records

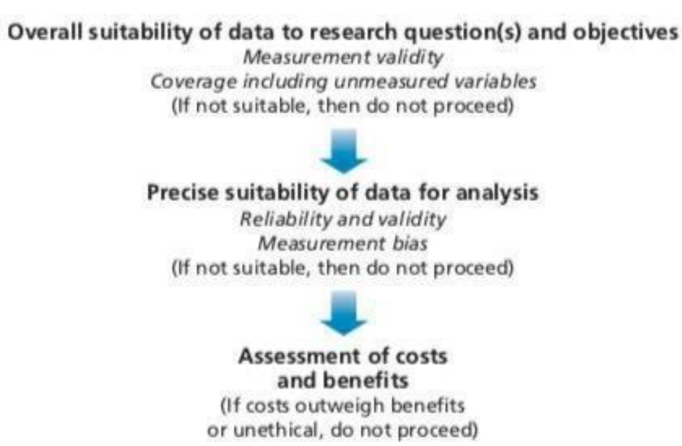
changes in the way data are collected
when the data collection technique did not measure the topic of interest

Evaluating Secondary Data Sources

Overall suitability:
- Measurement validity: measures should match with your need, but no solutions
- Coverage: ensure unwanted data are excluded and sufficient data are remained

Precise suitability:
- Reliability and validity

Costs and benefits



Chapter 11:

Questionnaires

general term to include all methods of data collection that each person is asked to respond to the same set of questions in a predetermined order
instrument
design of questionnaire affect the response rate and reliability and validity of the collected data
used for descriptive or explanatory research
work best with standardised questions that all respondents interpret the same way
only one chance to return collect data -> difficult to identify respondents or return to them to collect additional information -> so plan precisely
influenced by research question, objectives, resources available
6 main resource types: Internet, SMS, postal, delivery and collection, telephone, face-to-face → use data requirement table to ensure you collected all needed data
reliability and validity of data depend on → the design of questions, structure of questionnaire, rigour of pilot testing
used for descriptive or explanatory research
often part of survey collecting descriptive and explanatory data about facts, attitudes, behaviour
collected data analysed quantitatively
consider wording of individual questions prior to order of questions
used as data collection method only

Design:

visual appearance of questionnaire: attractive, easy to read and fill
be careful of intro question and of individual questions → high response rate
explain of purpose, pilot testing → high response rate
Self-completed questionnaire: usually completed by respondents, can be done electronically (e.g) survey
Interviews by researcher

Choice of questionnaire mode:

obvious attributes
mode you chose influences ensures reliability of response
uniformed response: answer is guessed
socially desirable answers in self completed questionnaires unlikely to answer

Resources available for a questionnaire choice:

time for data collection → use of cluster sampling makes it better
financial
availability of research assistants
cloud based survey design, data collection and analysis software

Computer aided personal interviewing (CAPI), computer aided telephone interviewing (CATI)

consider costs, availability
structured, semi-structured and unstructured(in-depth) interviews

person asked = respondent
Dillman's tailored design method for questionnaires how to use
many respondents asked many same questions → easy quantitative analysis

When to use

bad for many open questions
good when standardized
good for exploratory/ analytical (asked for relationship explanations of variables, cause and effect relations) or descriptive research (opinions asked)

To answer research question

review literature carefully
discuss ideas with colleagues
project tutors, other interested parties
review variables relationships

Types of data variables

Factual or demographic: data are readily available (e.g) characteristics such as age, gender, education, income,
Attitudes and opinions: contain data that need to think before answering
Behaviours and events: data about past, future, present (what people did in past, future do now)

How to ensure that collected data enables research question

create data requirement table consist of:
- For research objective: (e.g) employees attitude to smokers
- Type of research: predominantly descriptive (opinions), exploratory would be to differ between different restaurants and employees
- Investigative questions: need to answer in order to answer research question, goals (e.g) do people feel annoyed by smoking?
- variables required (e.g) opinion of employees
- details in which data is measured (e.g) strongly annoyed, not annoyed ○ relation to theory and key concepts in literature
- ○ check measurement question included in questionnaire

Question validity and reliability:

Valid questions: accuracy of data, data measures correct goal
Reliable questions: data collected consistently
Miscomprehension types:
- instructional: (e.g) wrong understood rank
- sentinel: respondent enriches or depletes syntax of a question (e.g) respondent answers a question about 'management' as her or his 'line manager'
- lexical: different meaning of some words (e.g) satisfied -> obligations being fulfilled, but interpreted as gratification

Validity

Internal validity = Measurement validity:

- what you find with your questionnaire represents the reality of what you are measuring
- if found measured data represents reality of what to measure

- Content Validity
  - coverage of investigated questions basically
  - the extent of collected data
- Criterion related validity = Predictive validity
  - predict customer future behaviour
  - make accurate predictions
  - use statistical analysis
- Construct validity
  - questions measure presence of construct
  - scales measure
- Convergent validity
  - different scales measure the same construct
  - overlap between scales
- Discriminant validity
  - distinctive

Reliability

- three approaches to achieve reliability: test re-test, internal consistency, alternative form
- test re-test:
  - estimates of reliability from the same questionnaire
  - depends on time interval
  - repondent completes questions twice
  - data collected under same conditions
- internal consistency:
  - measure consistency or responses between 0 and 1
  - Cronbach's alpha is used to calculate internal consistency
  - above 0.7 means consistent
- alternative form
  - find alternative questions and compare responses
  - called as check questions
  - difficult to ensure that the questions are equivalent ○ advised to use check questions

Open Questions

- give answers in their own way
- useful in exploratory research when you require detailed answer
- too much space becomes off-putting
- respondents tend to write more when answering on internet
- time consuming so use to minimum

Closed Questions

- closed-ended questions or forced-choice questions
- quicker and easier to answer
- predetermined responses can be misunderstood by respondents so become invalid
- issues with translating into other languages

automated and pre-coded for facility
types: list, category, ranking, rating, quantity, matrix

List Questions

list of responses that can choose one or more
useful when respondents considered all possible responses
use of ‘other’ can result in unforeseen responses where the question is considered intrusive
respondents may not read the list and just click
don’t mention religion
select any (e.g) demographic data, what is your religion select a, b, c

Category Questions

answer only one category
useful to collect data about behavior or attributes
number of categories depends on the type of questionnaire
self-completed and telephone questionnaires should have no more than five categories
researcher-completed questionnaires can have more categories with prompt card
should be arranged in logical order
categories should be mutually exclusive

Ranking Questions

place in rank order
discover relative importance
clear instructions and understanding needed
ranking more than seven items reduce motivation
overcome face-to-face questionnaires
use fewer items for telephone questionnaires

Rating Questions

collect opinion data
rating device used to record response
should not be confused with scales
frequently use likert-style rating
Likert-style rating: respondent is asked how strongly aggress or disagrees with a statement usually on 4-7 rating scale (MBTI 검사지 생각하기)
possible responses presented in straight line
include both positive and negative response -> keep the same order
‘not sure’ or ‘I don’t know’ can be added but should be separated
Semantic differential rating question: used in consumer research, each bipolar rating scale is described by opposite adjectives, should vary position of positive and negative adjectives from left to right to reduce to tendency to ready only on the left

Combining Rating Questions into Scales

measure wide variety of concepts
(e.g) customer loyalty, service quality, job satisfaction

constructs exist by measures combined into scale that measures the construct
each rating question is a scale item
reverse coding (reverse scoring): high values indicate the same type of response on every item
create scales to measure constructs by combining rating questions
quantity: response is a number of amount
matrix: responses to two or more questions by combining rating questions

Design individual questions

adopting questions
adapting questions:to replicate or compare results
developing questions

Response categories of different types of rating questions:

Agreement
Amount
Frequency
Likelihood
Scales measure different types of rating

Translating questions into other languages:

Pay attention on:

- Lexical meaning: precise meaning of individual words (e.g) chaud can be translated into hot and warm)
- Idiomatic meaning: only natives can understand the meaning (e.g) Grapevine means mouth propaganda
- Experiential meaning: use familiar words to everyone
- Grammar and syntax: correct ordering of words and phrases

Coding question responses

question responses coded before entry
cloud tool automatically does it
you need to DIY for paper based questionnaires
closed questions: codes are given to each category so pre-coding after data collection
open questions: more complex coding using multiple-response or multiple-ditchotomy method
Use **pre-coding** symbols for easier removing need to code after collection
Direct Translation:

- Source questionnaire (S) → Target questionnaire (T)
- easy, cheap
- many errors

Back Translation:

- S → T, T→ S, comparison → final questionnaire
- discover problems
- easy to implement with translators
- need two translators and target language

Parallel Translation:

S→ T and S→ T, parallel by two independent translators → comparison → choose final out of two
good wording of target language
cannot ensure exclusion of lexical, experimental, idiomatic meanings

Order and flow of questions

need to include filter questions
identify respondents that the questions are not applicable for them so they can skip the questions
(e.g) are you currently...is yes... if no go to…

Visualisation:

colors and blbla
do not make questions too long and too much

Introducing the questionnaire

covering letter: welcome screen
especially stress that participation is voluntarily

Closing the questionnaire

explain what you want the respondent to do with their completed questionnaire at the end of questionnaire
state when, where to return with your name and address

Pilot testing

purpose: refine questionnaires so that respondents do not have issues to answer questions and let it record
should be pilot tested before questionnaire
if you don't do pilot testing -> will at least provide face validity (whether questionnaire make sense)
do pilot test with similar respondents
obtain assessment on validity and reliability
use investigation question
number of people you let undertake pilot test depends on research question
start with individual questions and then larger and more rigorous pilots
insufficient financial or time for smaller scale survey
10 is the minimum number for students
between 100 and 200 responses for large surveys

Delivering and collecting questionnaire:

can be used when questionnaire designed, pilot tested and sample selected
postal delivery and such + communication and such

Internet questionnaire:

use netiquette

avoid cross-posting (sending emails in multiple groups, individual end up getting copies of same mail)

Chapter 12:

Raw quantitative data

has not processed or analysed
convey very little meaning need
to be processed

Quantitative data

refer to all numerical primary and secondary data
help researcher to answer research questions
categorical data and numerical data

Categorical data

non-numerical data
can be quantified by classifying into sets/categories
can be classified into sets/categories
can be placed in rank order

Two types of data:

Descriptive/nominal data:

count the number of occurrences in each category of a variable

data are known as dichotomous data when a variable is divided into two categories (e.g) female, male

Ranked/ordinal data:

more precise than categorical data
(e.g) answers to rating or scale questions

Numerical data:

values are numerically measured or counted as quantities
more precise than categorical ones
can assign each data value a position on a numerical scale ○ can be subdivided in two ways

based on interval and ratio data based on continuous and discrete datainterval data:

state the difference (interval) between any two data values of a certain variable (e.g) 20 degrees and 30 degrees

ratio data:

calculate the relative difference (ratio) between any two data values of a certain variable (e.g) profit difference

continuous data:

values can take any value (given that you measure them accurately) (e.g) delivery distance, length of service

discrete data:

measured precisely, often whole numbers/integers (e.g) number of phones produced

Preparing data for quantitative analysis

be clear about:

definition and selection of cases:

units for which data has been collected

(e.g) commercial, advertisement

data type or types scale of measurement

our datatypes from BI

dichotomous data : two categories pass/fail

numerical codes used to classify data to ensure they enable research question

comparisons with other findings, save time, normally well tested

descriptive what happened vs predictive what will be

coding scheme covers variety of data→ use code book used for open and visual questions

when coding make clear: level of precision, coding schemes choice

Content analysis

categorizing and coding text, voice and visual data to enable quantitative analysis
Manifest analysis: visible components in data that can be counted
Latent content: lie behind manifest, imaginary

5 Principles of systematic development of variables categories

linked to research question
mutually exclusive fit to one category only
independent categories
subcategories
developed from single classification to avoid confusion
processed if categories are transparent → calculate percentage agreement
(PA = A/n *100) A number of agreements btw two coders, n segments coded

Coding categorical data

suitable coding scheme is already devised when the data were collected for many secondary data sources (government surveys)
need to decide coding scheme for other secondary data (text, voice) and all primary data
need to have highest precision before coding
existing coding schemes

can be used for many variables

- save time
- normally well tested
- can compare to other findings

Coding numerical data

re-coding: use analysis software to combine data to form additional variables with less detailed categories (e.g) 53543 (numerical discrete data) -> $50000 (categorical ranked data)

Coding missing data

choice of code to represent missing data is up to you

will not affect your result if data are missing at random

Data layout

data matrix: data entered in table (row: case, column: variable)
secondary data in a matrix: data already stored in a file
multiple response method: same number of variables as maximum number of different responses
multiple dichotomy method: use separate variable for each different answer

Check data for errors

look for:

- illegitimate codes
- illogical relationships
- do questionnaire data check
  - filter questions

not doing it is dangerous

each case needs a unique identifier number

Weightening your cases

the weight is 1 if your calculations are correct

highest proportion / portion of population for calculating weight

Exploratory Data analysis:

use graphs for data

exploring individual variables:

- tables:
  - easiest way of summarising the data
  - do not demonstrate highest or lowest values -> diagrams are a better option for summarising the data
- bar chart:
  - height or length of each bar represents the frequency of occurrence
  - show highest and lowest
  - similar to histograms
- pictogram:
  - similar to a bar chart
  - shows a series of pictures to represent the data
- line graph:
  - suitable to explore a trend
- Pie chart:
  - diagram is divided into proportional segments based on the share eachhas of the total value

p.584 (see which data is best described by which graph)

To show relative amounts

Word cloud: keywords frequency of a word occurance arecolored
Histogram: each bar represents the frequency pf pccurrence and continuous nature of data is emphasized by gaps between bars
Pictogram: each bar is replaced by a series of pictures to represent data

o show a trend

line graph

To show proportions or percentages

pie chart

To show distribution of values

frequency polygon: line graph connected to a mid point
positively skewed: bunching to left and long tail to right
negatively skewed: bunching to right and long tail to left
symmetrically distributed: data are equally distributed
normal distribution: bell-shaped curve
kurtosis: flatness is compared with normal distribution
box plot: include statistical software

Comparing variables

To show interdependence and specific amounts

contingency table (cross tabulation): show interdependence between variables

To compare highest and lowest values

multiple bar graph (compound bar graph): highest and lowest rather than precise values

To compare proportions or percentages

percentage component bar graph (divided bar graph): compare cumulative totals

To compare trends so the intersections are clear

multiple line graph: one line represents variable

To compare cumulative totals

stacked bar graph: used for all data types

To compare proportions and cumulative totals

comparative proportional pie charts: used for all data types

To show interrelationships between cases for variables

scatter plot: interrelationships between ranked and numerical variables
dependent variable: changes
independent variable: against vertical axis

Descriptive statistics

describe variables data numerically
described by dispersion: differences and comparisons
ranges (rare use, expresses extreme vals): lower range, inter quartile range, upper lower range

Central tendency

middle/median and lowest highest value
mean, median, mode describe tendency
mode: values that occurs most frequently
median: rank all values in ascending order and find mid point
mean: most frequently used to measure central tendency (numerical data)
trimmed mean: extreme data excluded from calculations

Describing dispersion

only for numerical data
table frequency distribution: best way to summarize independent data variables
inter-quartile range and standard deviation are used to describe dispersion

1. divide the standard deviation by the mean
2. then to multiply your answer by 100

coefficient of variation: result of standard deviation

Type I error

error made by rejecting null hypothesis -> accept null hypothesis (there is a relation)
statistical significant: probability of making Type I error

Type II error

error made by accepting null hypothesis -> reject null hypothesis (there is no relation)

Null hypothesis

testable explanation

Non-directional and directional hypothesis

includes direction of difference not only difference itself

Effect size index

measure size of differences

Testing for whether two variables are independent or associated

Chi square: test if variables are independent

Cramers’sV and Phi: test if variables are associated

Testing for normal distribution

Kolomogorov Smirnov: for ranked data if variables differ from specified population
Shapiro Wilk test: test for normality in distribution and other differences probability < 0.05 -> data is not normally distributed

Testing for numerical data

Independent group t test: two distinct groups
Paired t test: pairs of data before and after
T test: ignored without too many problems
ANOVA: analyses the variance -> tspread of data values between groups by comparing means

Correlation coefficient to assess strength of relationship between pairs of variables

quantify the linear relationship between two ranked or numerical variables.
can take on any value between + 1 and − 1
+ 1: positive correlation -> two variables are precisely related, proportional relationship
– 1: negative correlation -> two variables are precisely related, not proportional relationship
between + 1 and – 1: weaker positive and negative correlations,
0: variables are independent
If both your variables contain numerical data: use Pearson’s product moment correlation coefficient (PMCC)
Spearman’s rank correlation coefficient and Kendall’s rank correlation coefficient:

- used most widely in business and management research
- both rank correlation coefficients assume that sample is selected at random and the data are ranked (ordinal)

Coefficient of determination to assess strength of cause and effect relationship between dependent and independent variables

Correlation and regression: test to assess strength of relationships between variables
Coefficient of determination: between numerical dependent variable and one independent variable
Coefficient of multiple determination: between numerical dependent variable and two or more independent variables
Regression analysis: predict values, process of calculating the coefficient of determination and regression equation using one independent variable is normallyMultiple regression analysis: calculating a coefficient of multiple determination and regression equation using two or more independent variables

Predicting the value of a variable from one or more other variables

Homoscedasticity: data values for the dependent and independent variables have equal variances
Collinearity or multicollinearity: absence of correlation between two or more independent variables, difficult to determine the separate effects of

individual variables.

Exploring the trend

use index numbers and base period

Determining trend and forecasting

Durbin–Watson statistic:

discover whether the value of your dependent variable at time *t* is related to

its value at the previous time period ($t-1$)
autocorrelation or serial correlation is important because it means that the results of your regression analysis are not reliable

Longitudinal data may select techniques of

index numbers to establish a trend or to compare trends between variables
moving average and regression analysis to determine trend and forecast

Chapter 7:

Sample

should always represent full set of cases
leads to higher accuracy
focus on smaller number of cases to collect data so more detailed
more time to design and pilot data

Population

full set of cases
can point people, region and cars
better option than census
no budget
no time
not practicable

Sampling techniques

choice of sampling techniques depends on feasibility and sensibility data
Population sampling: collect data from entire population
Select and collect data from every possible group member - census - subgroup - sample
Target population: subset of population, actual focus of research inquiry

Sampling techniques to select cases for target

Multistage sampling = Probability sampling:
- case is known
- equal for all cases
- possible to answer research questions
- representative sampling(perfect target representation)

- generalize target populations from data using statistical probability samples
- common with survey research strategies

Non probability sampling:

- case is unknown
- not possible to answer research question but still can answer ‘What job attributes-‘, ‘How are financial services-‘
- can generalize, but not statistical way
- no rules to decide sample size

Suitable sample size

larger size -> less error

choice of sample size is governed by:

confidence one has in the data (whether you are certain that the sample is representative of the entire population)

margin of error one tolerates (the accuracy for estimates made from the sample)

type of analyses one is going to undertake ○ size of the total population

Sampling frames

complete list of all cases in target population

Central limit theorem

larger the absolute size of a sample, the closer its distribution will be to the normal distribution and more robust

Statistical inference

process of coming up with conclusions about population on basis of data describing the sample

allows you to calculate how probable it is that your result

Law of large numbers

larger sample size, more→ better

doing same experiment many times

Representative sample

exactly represents the target population

Non-response bias

bias resulting from respondents differing in meaningful ways from non-respondents

levels of non-responses

complete refusal: no questions answered

break-off: less than 50 per cent of all questions answered

partial response: 50 per cent to 80 per cent of all questions answered

complete response: over 80 percent answered

Reasons for non-response
refusal to respond
ineligible to respond
not possible to locate respondent
respondent located but unreachable
total response rate= total number of responses / (total number in sample - ineligible)
active response rate = response rate excludes ineligible respondents who were unreachable = total number of responses / (total number in sample- (ineligible+unreachable))
actual sample size required = n*100 / re% (n = minimum sample size, re% = estimated response rate as %)

Techniques to select a probability sample

choice depends on research question Simple
random sampling (random sampling)
- select sample at random from sampling frame using spreadsheet's random number generator or function
- accurate and easy to access
- better with over 100 sample sizes
- area is concentrated if face-to-face, otherwise do not matter
- high cost for large sample size
- difficult to explain

Systematic random sampling (systematic sampling)
- select sample at regular intervals from sampling frame
- sampling fraction = actual sample size / total population
- accurate and easy to access
- not containing periodic patterns
- for all sample sizes
- area is concentrated if face-to-face, otherwise do not matter
- low cost
- easy to explain
- no difference with simple random

Stratified random sampling
- modification of random sampling that you devide target population into two or more relevant and significant strata based on one or number of attributes
- stratification variable should represent discrete characteristic
- accurate and easy to access
- divisible to relevant strata
- area is concentrated if face-to-face, otherwise do not matter
- low costs if strata is available
- difficult to explain
- better than simple random
- response rats need reweighting

Cluster sampling (one-stage cluster sampling)
- based on grouping
- accurate and easy to access
- for large samples
- dispersed if face-to-face required
- geographically based clusters
- low costs if clusters are provided
- difficult to explain until clusters selected
- quicker but less precise than simple random

Types of non-probability sampling

Data saturation:

no new data and redundancy shows that data collection can stop/cease
inappropriate for some research questions

Quota sampling:

non-random and used as an alternative to probability sampling for internet and interviewer completed questionnaires as part of a survey strategy high likelihood
useful for cost constrained or data needs quickly
medium – expensive
specifies quota criteria

Purposive sampling:

need to use your judgement to select cases that will best enable to answer your research questions
known as judgemental sampling ○

Extreme case or deviant sampling:

specifies unusual or special cases based on data collected aboutunusual or extreme outcomes

low likelihood

cost

used to reveal insight to explain typical stuffs
reasonable cost

Heterogeneous or maximum variation sampling:

use judgement to choose participants with diverse characteristics to provide maximum variation

low likelihood

used to reveal key themes
reasonable costs

specifies criteroa for maximum diversity

Homogeneous sampling:

focuses on one particular subgroup that all the sample members aresimilar

low likelihood

used to reveal minor differences
reasonable cost

specifies criteria to identify particular group

Critical case sampling:

selects critical cases

logical generalisations can be made ○

Typical case sampling:

enable researcher to generate illustration of who will read and

unfamiliar with the topic

Theoretical sampling:

sample selection is dictated by needs of theory developed

sampling occurs during the research if more participants are needed

Voluenteer sampling

Snowball sampling:

technique to look at where participants volunteer to be part of the research rather than being chosen
development of snowball sampling is respondent driven sampling (RDS)
useful for difficult cases to identify

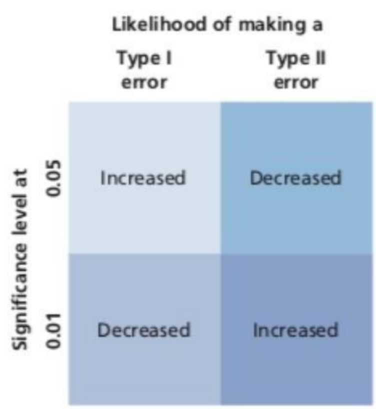
Self-selection sampling:
occurs when researcher asks individuals to volunteer research
useful for difficult assess

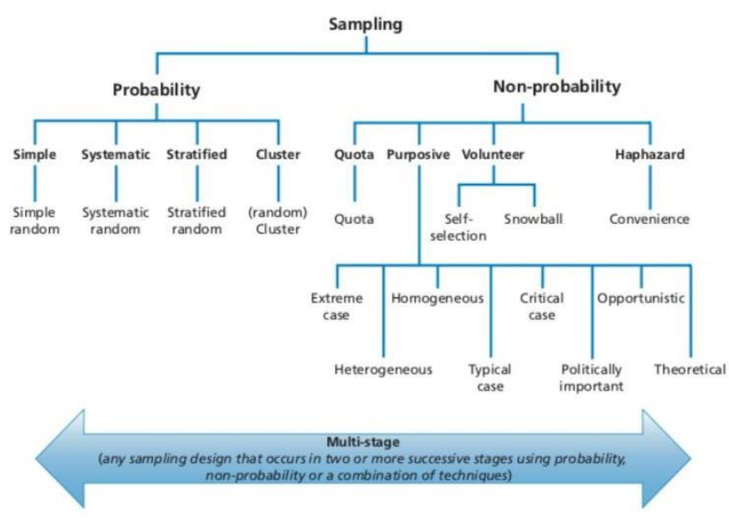
Haphazard sampling

occurs when sample cases are selected without any obvious principles of organisation in relation to your research question
most common form is convenience sampling (availability sampling): select because it is easy

Multi-stage sampling

any sampling design that occurs in two or more successive stages using either probability, non-probability, or both





Module 6 overview: Consumer Products

! Disclaimer: always check what you need to study corresponds with the content of the summaries, courses can be changed which could cause changes in study material for your exams

Below you find information about which courses you have this module, and about the summaries for this module. If you made a summary for a course this module you can send them to education@stress.utwente.nl and depending on how many summaries we have for this course you will receive compensation for your work.

Courses

- Technical Product Modelling
- Production
- Sustainable Supply Chains for Consumer Products
- Skills
- Project

Summary 1

Course: Sustainable Supply Chains for Consumer Products*
Book: -
Year the summary was received: 2020

Summary 2

Course: Production 1*
Book: Kalpakjian, S.; Schmid, S.R.. (2013) *Manufacturing Engineering and Technology*, Pearson
Year the summary was received: 2020

Summary 3

Course: Technical Product Modelling
Book: - Reader Technical Drawing
Year the summary was received: 2020

Summary 4

Course: Product Market Relations*
Book: -
Year the summary was received: 2023

* There is another summary available on www.stress.utwente.nl

Summary 1: Sustainable supply chains for consumer products

Sustainability is the endurance of systems and processes.

Sustainable development is a development that meets the needs of the present without compromising the ability of future generations to meet their own needs.

Sustainability counts on **the three P's**:

* **Planet – environmental sustainability**
* **People – social sustainability**
* **Profit – economic sustainability**

Environmental sustainability includes greenhouse gas emissions, water use, land use, etc.
Social sustainability includes change in income, health impact, etc.
Economic sustainability includes productivity, net energy balance, etc.

There are **17 global goals for sustainable development**.

Sustainable Business Development (SBD) is a **holistic management construct** that includes the entire value system from the origin of the raw materials to production processes and customer applications to end-of-life solutions. SBD covers the **full scope of relationships** with supply networks, customers and stakeholders and support service providers for providing business solutions and also handling wastes, residuals and **impacts**.
SBD does this through the management concepts of **enterprise management** and **life cycle thinking**, building an organization's **awareness** and strategic management to encompass the appropriate **mindset well beyond its direct actions**.

There are several factors that influence the products' sustainability. Such factors are:

* The function of the product and its contribution to environment, society, and economy.
* The material and energy types consumed, and waste emissions caused during the life cycle of the product.

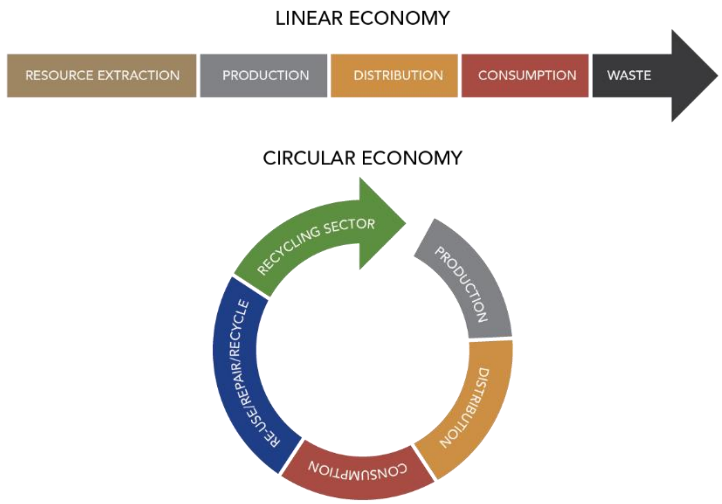
A product is green when its environmental and societal performance, in production, use and disposal, is significantly improved and improving in comparison to conventional or competitive products offerings.
A green product-based business is differentiated when it created products that provide greater environmental benefits, or that impose smaller environmental costs, than similar products.

An ecolabel is a voluntary environmental performance certificate that is awarded to products and services. These products and services have to meet specific, identified criteria depending on the product groups, which reduce overall environmental impact.

Sustainable supply chains – reducing sustainability risks and increasing overall supply chain performance:

* Globalized supply chains, outsourcing, increased number and type of suppliers, etc.
* Supplier assessment schemes to avoid risks.
* Need for improving overall supply chain performance, not only traditional performance measure.

A **circular economy** would turn goods that are at the end of their service life into resources for others, closing loops in industrial ecosystems and minimizing waste. It would change economic logic because it replaces production with sufficiency: *reuse what you can, recycle what cannot be reused, repair what is broken, remanufacture what cannot be repaired*.



A **social sustainability indicator** is the wellbeing of people.

The **supply chain** encompasses all activities associated with the flow and transformation of goods from raw materials stage (extraction), through to the end user, as well as the associated information flows. Material and information flow both up and down the supply chain. **Supply chain management (SCM)** is the integration of these activities through improved supply chain relationships to achieve a sustainable competitive advantage.

Three things flow in a supply chain: **Physical flows, Information flows,** and **Monetary flows.**

Pressures and incentives for sustainability in supply chains:

* Legal demands/regulations
* Customer demands
* Response to stakeholders
* Competitive advantage
* Environmental and social pressure groups
* Reputation loss

Barriers for sustainable supply chain management:

* Higher costs
* Coordination complexity/effort
* Insufficient/missing communication in the supply chain

Supporting factors for sustainable supply chain management:

* Company-overlapping communication
* Management systems
* Monitoring of sustainability performance, evaluation, reporting, sanctions
* Training education of purchasing employees and suppliers
* Integration into the corporate policy

Sanctions stimulate suppliers to become more sustainable.

Industrial Symbiosis (IS) engages traditionally separate industries in a collective approach to competitive advantage involving physical exchange of materials, energy, water, and by-products.

Sustainability performance indicators

* People, planet, profit – 3 P's of sustainability.

* Social, environmental and economic indicators.
* Should engage all relevant stakeholders.
* Energy and water consumption, greenhouse gas emissions, resources depletion, green jobs, health risks, profit, value-added.
* NGO's, governments, companies, people, ecosystem.

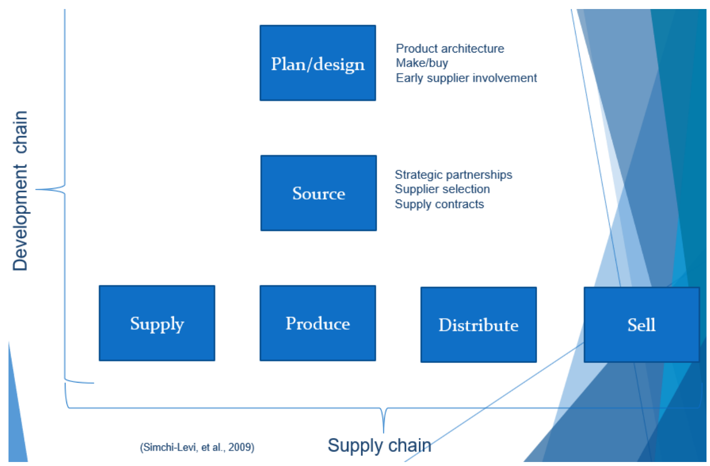
Circular design and business model strategies

Supply chain management is a set of approaches utilised to efficiently integrate **suppliers, manufactures, warehouses, and stores**, so that merchandise is produced and distributed at the right **quantities**, to the right **locations** and at the right **time**, in order to **minimize** systemwide costs while satisfying service level requirements.

Challenges in supply chain management:

* **The development chain:** set of activities associated to new product introduction.
* **Global optimization:** the process of finding the best systemwide strategy.
* **Uncertainty and risk management**: design to eliminate the uncertainties and risks as much as possible.

The development chain is illustrated in the following picture:



Managing uncertainty and risk:

* Matching supply and demand
* Inventory and back-order levels fluctuate
* Forecasting does not solve the problem
* Demand is not the only source of uncertainty
* Lean manufacturing and outsourcing increase risks

Product design plays a critical role in the supply chain.

Sustainable product design strategies:

* **Decoupling concept:** rethinking how to meet the need for growth while at the same time reducing negative environmental and social impact. Decoupling is of great importance as it seeks to break the link between economic growth and environmental degradation.
* **Cleaner production:** the continuous application of an integrated preventive environmental strategy to processes and products to reduce risks to humans and the environment. This strategy has been proven to be cost-effective.

Sustainable products:

* Low environmental impact
* Repairable and recyclable

The goal of **redesign** is to sustainably redesign an existing product for which the specific market and manufacturing conditions are already known, taking into account its primary function and the associated services provided.

The goal of **benchmarking** is to learn from the best practice of competitors by comparing one's product to those of competitors to determine how to make that product more sustainable. Benchmarking differs from redesign in that it starts with comparing existing products in the market before moving into the design phase.

The **new product development** approach applies radical innovation strategies, which can lead to more sustainable impacts while providing the breakthroughs necessary to ensure a company's continued competitiveness. New product development involves a higher level of technical, market, and organizational uncertainty than redesign but can be an inventive and interactive process where new ideas on how to meet needs are converted to products and services. The stages and processes involved with new product design can be viewed as three-fold: policy formulation, idea generation, and product development.

Product service systems (PSS) use different ways of addressing at the design stage what a customer really needs and the way a product is designed, produced used and discarder. PSS can be an effective function-based strategy that concentrates on "satisfaction" as a product value instead of private ownership of physical products.

Sustainable innovation and design is not necessarily about new technologies, but about rethinking how to meet everyone's needs of sustaining growth without costly environmental and social impacts.

Resource cycles:

* Cradle-to-grave (linear) vs. cradle-to-cradle design (circular)
* Closed-loop systems: reuse of goods and recycling of materials

The **reuse of goods** means an extension of the utilization period of goods through the design of long-life goods. The result of the reuse of goods is a slowdown of the flow of materials from production to recycling.

Resource cycles: slowing and closing loops

* **Slowing resource loops:** Through the design of long-life goods and product-life extension, the utilization period of products is extended and/or intensified, resulting in a slowdown of the flow of resources.
* **Closing resource loops:** Through recycling, the loop between post-use and production is closed, resulting in a circular flow of resources.

These two approaches are distinct from a third approach toward reducing resource flows:

* **Resource efficiency or narrowing resource flows**, aimed at using fewer resources per product.

There are multiple **design strategies** to slow and close loops.

Design strategies to slow loops:

* Designing long-life products
    - Design for attachment and trust
    - Design for reliability and durability

* Design for product-life extension
    - Design for ease of maintenance and repair – **maintenance** is the performance of inspection and/or servicing tasks to retain the functional capabilities of a product.
    - Design for upgradability and adaptability – **upgradability** is defined as the ability of a product to continue being useful under changing conditions.
    - Design for standardization and compatibility
    - Design for dis- and reassemble

Design strategies to close loops:

* Design for a technological cycle – for products of service – designers aim to develop products in such a way that the materials can be continuously and safely recycled into new materials or products.
* Design for a biological cycle – products of consumption – products designed with safe and healthy materials that create food for natural systems across their life cycle.
* Design for dis- and reassembly – it is about ensuring that products and parts can be separated and reassembled easily.

Business models to slow/close loops:

* **Access and performance model:** Providing the capability or services to satisfy user needs without needing to own physical products. Deliver capability rather that ownership **(slowing)**
* **Extending product value:** Exploiting residual value of products – form manufacture, to consumers, and then back to manufacturing – or collection of products between distinct business entities. **(slowing)**
* **Classic long-life model:** Business models focused on delivering long-product life, supported by design for durability and repair for instance. **(slowing)**
* **Encourage sufficiency**: Solutions that actively seek to reduce end-user consumption through principles such as durability, upgradability, service, warrantees and reparability and a non-consumerist approach to marketing and sales. **(slowing)**
* **Extending resource value**: Exploiting the residual value of resources: collection and sourcing of otherwise wasted materials or resources to turn these into new forms of value. **(closing)**
* **Industrial Symbiosis**: A process-oriented solution, concerned with using residual outputs from one process as feedstock for another process, which benefits from geographical proximity of businesses. **(closing)**

Reduce: decreasing the generation of wate makes sense and has proven highly effective for consumer goods. <u>For example</u>, new concentrated products such as laundry and dishwashing detergent offer benefits by reducing packaging and transportation requirements. Reducing the size and weight of a product can have a positive environmental impact. Reducing size and weight does not work for many categories of durable goods.

Reuse: shifting a culture from the disposable to the reusable has worked well in general.

Recycling: recycling comes last in the hierarchy of waste management techniques for decreasing landfill disposals but has generally has the greatest environmental impact to date.

Rethink: rethinking the environmental challenges posed by durable goods wate also provides interesting opportunities for businesses. A rethinking of the problem should start with an examination of the ecological impact and economics across the full product life – from manufacture through use, reuse, recycling, and disposal. The economic incentives for the various industry players must also be considered, including original equipment manufacturers (OEMs), retailers, service providers, remanufacturers, recyclers, and waste management companies.

Design decisions can affect the economic and environmental performance in different stages of the phone's life cycle by affecting the manufacturer's costs and consumer demand, as well as the environmental impact at different stages.

Matrix algebra

A **matrix** is a two-dimensional array of numbers of formulas.

A **vector** is a matrix with either only one column or only one row. A **column vector** has only one column. A **row vector** has only one row.

The **m×n matrix**: The **dimension of a matrix** is expressed as the number of rows (m) × the number of columns (n).

A **k-dimensional vector** y is an ordered collection of k real numbers $y_1, y_2, \dots, y_k$, and is written as $y = [y_1, y_2, \dots, y_k]$. For example: $y = [-2; 3; 1; 0; 4]$ is a 5-dimensional vector.

A **matrix** is defined to be a rectangular array of numbers

$$A = \begin{bmatrix} a_{11} & a_{12} & \dots & a_{1n} \\ a_{21} & a_{22} & \dots & a_{2n} \\ \dots & \dots & \dots & \dots \\ a_{m1} & a_{m2} & \dots & a_{mn} \end{bmatrix}$$

whose dimension is m×n.

* If $m = n$, then we have a **square matrix**
* If $m \neq n \; and \; n \neq 1 \wedge m \neq 1$, then we have a **rectangular matrix**
* If $m \neq n \wedge m = 1$, then we have a **row vector**
* If $m \neq n \wedge n = 1$, then we have a **column vector**

Two matrices A and B are said to be **equal**, written $A = B$, if they have the same dimension and their corresponding elements are equal.

Scalar multiplication (example)

The main formula for a **scalar multiplication** is: $\boldsymbol{B = k * A}$

In this case $k = 5$ and $A = \begin{bmatrix} 0 & 5 \\ -1 & -2 \\ 3 & -3 \end{bmatrix}$

Then $B = k * A = 5 * \begin{bmatrix} 0 & 5 \\ -1 & -2 \\ 3 & -3 \end{bmatrix} = \begin{bmatrix} 0 & 25 \\ -5 & -10 \\ 15 & -15 \end{bmatrix}$

Summation/Addition (example)

The main formula when **summating** two matrices is: $\boldsymbol{A + B = C}$

In this case $A = \begin{bmatrix} 5 & 3 \\ 4 & 6 \end{bmatrix}$ and $B = \begin{bmatrix} 0 & -2 \\ -1 & -3 \end{bmatrix}$

Then $C = A + B = \begin{bmatrix} 5 & 3 \\ 4 & 6 \end{bmatrix} + \begin{bmatrix} 0 & -2 \\ -1 & -3 \end{bmatrix} = \begin{bmatrix} 5+0 & 3+(-2) \\ 4+(-1) & 6+(-3) \end{bmatrix} = \begin{bmatrix} 5 & 1 \\ 3 & 3 \end{bmatrix}$

In order to execute the summation, the sizes of the matrixes should be equal. Otherwise the summation cannot be done.

Multiplication (example)

The main formula when executing a **multiplication** between two matrices is: $\boldsymbol{A * B = C}$**. Here A is an m×p matrix and B is an p×k matrix.**

In order to execute the multiplication, the number of columns of matrix A should be equal to the number of rows of matrix B.

In this case $A = \begin{bmatrix} 5 & 3 \\ 4 & 6 \end{bmatrix}$ → a 2×2 matrix

and $B = \begin{bmatrix} -2 & 1 & 3 & 4 \\ 2 & 0 & 0 & 2 \end{bmatrix}$ →a 2×4 matrix

Then $C = \begin{bmatrix} 5(-2)+3*2 & 5*1+3*0 & 5*3+3*0 & 5*4+3*2 \\ 4(-2)+6*2 & 4*1+6*0 & 4*3+6*0 & 4*4+6*2 \end{bmatrix} = \begin{bmatrix} -4 & 5 & 15 & 26 \\ 4 & 4 & 12 & 28 \end{bmatrix}$

With multiplying matrices, the following rule is important: $\boldsymbol{AB \neq BA}$

Identity matrix

The **identity matrix** of order m, written I_m, is a square matrix with ones along the diagonal and zeros elsewhere.

For example, $I_3 = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$

For any m×n matrix B: $\boldsymbol{BI_m = I_mB = B}$

Some properties of matrices

* $\boldsymbol{A + B = B + A}$
* $\boldsymbol{A + (B + C) = (A + B) + C}$
* $\boldsymbol{A(BC) = (AB)C}$
* $\boldsymbol{A(B + C) = AB + AC}$

Transpose matrix

The **transpose** of matrix A, denoted $\boldsymbol{A^t}$**,** is formed by interchanging the rows and columns of A. So, **the rows become columns and the columns become rows**.

$$A = \begin{bmatrix} 2 & 1 \\ 0 & -3 \\ -2 & 5 \end{bmatrix} \rightarrow A^t = \begin{bmatrix} 2 & 0 & -2 \\ 1 & -3 & 5 \end{bmatrix}$$

$$\boldsymbol{(AB)^t = B^tA^t}$$

$$A = \begin{bmatrix} 2 & 1 \\ 0 & -3 \\ -2 & 5 \end{bmatrix} \; and \; B = \begin{bmatrix} 2 & -1 & 0 \\ 0 & -2 & -1 \end{bmatrix}$$

$$A * B = \begin{bmatrix} 4+0 & -2-2 & 0-1 \\ 0 & 6 & 3 \\ -4 & 2-10 & -5 \end{bmatrix} = \begin{bmatrix} 4 & -4 & -1 \\ 0 & 6 & 3 \\ -4 & -8 & -5 \end{bmatrix} \rightarrow AB^t = \begin{bmatrix} 4 & 0 & -4 \\ -4 & 6 & -8 \\ -1 & 3 & -5 \end{bmatrix}$$

$$A^t = \begin{bmatrix} 2 & 0 & -2 \\ 1 & -3 & 5 \end{bmatrix} \; and \; B^t = \begin{bmatrix} 2 & 0 \\ -1 & -2 \\ 0 & -1 \end{bmatrix} \rightarrow A^t * B^t = \begin{bmatrix} 4 & 0 & -4 \\ -4 & 6 & -8 \\ -1 & 3 & -5 \end{bmatrix}$$

Inverse matrix

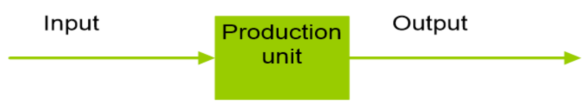
Given a square m×n matrix B, if there is an m×n matrix D such that $DB = BD = I$, then D is called the **inverse of B** and is denoted $\boldsymbol{B^{-1}}$.

$$\boldsymbol{B^{-1} = IB^{-1} = (AB)B^{-1} = A\left(BB^{-1}\right) = AI = A}$$

Input-output modelling for sustainability analysis

Input-output analysis describes and explains the production level of each sector of a given country's economy, in relation to the correspondent activity levels of all other sectors. The model is composed of a logical and mathematical structure which can count the **flows of goods** existing between various sectors where the splitted economy of a country is considered. The model is capable to fix how these flows vary as the function of some characteristic changes of the productive system.

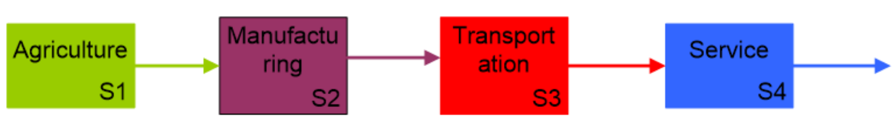
The **basic components** of an input-output model are shown in the following picture.



Dependence (example):

Interdependence (example):

Indirect and iduced independence:

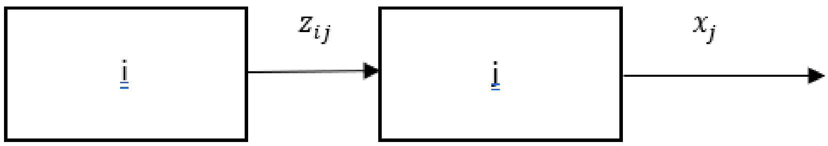


* Agriculture → Manufacturing: **direct dependence**
* Agriculture → Transportation: **indirect dependence**

* Agriculture → Service: **induced independence**

Secundary dependence is also reffered to as **indirect dependence**. When the relation is tertais, you call it **induced dependence**.

Technical coefficient (physical)



* $\boldsymbol{z_{ij}}$ = total output flows from sector i to sectorj.
* $\boldsymbol{x_j}$ = total (produced) output of sector j.
* $\boldsymbol{a_{ij}}$ = **technical coefficient**, i.e. output flow from sector I to sector j required to produce one unit of output of sector j.

$$\boldsymbol{a_{ij} = \frac{z_{ij}}{x_j}}$$

From a sustainability perspective you want the technical coefficient (physical) to be a small as possible.

Technical coefficient (monetary)

* $\boldsymbol{p_i}$ = price of output unit of sector i.
* $\boldsymbol{p_j}$ = price of output unit of sector j.
* $\boldsymbol{a'_{ij}}$ = **technical monetary coefficient** i.e. output flow (as value) from sector i to sector j required to produce the output of sector j having 1-euro value.
* $\boldsymbol{z'_{ij}}$ = total output flows (as value) from sector i to sector j.
* $\boldsymbol{x'_j}$ = total (produced) output (as value) of sector j.

$$\boldsymbol{a'_{ij} = \frac{z'_{ij}}{x'_j} = \frac{p_i * z_{ij}}{p_j * x_j} = \left(\frac{p_i}{p_j}\right) * a_{ij} \rightarrow z'_{ij} = a'_{ij} * x'_j}$$

The input-output model assumes that the interdependences between sectors are computed under a certain **constant technology**.

Example:
If we nee 60 MWh electric energy (z_{ij}) to produce 120 tons of iron (x_j), the technical coefficient is

$$a_{ij} = \frac{z_{ij}}{x_j} = \frac{60}{120} = 0.5\ MWh/ton$$

If electricity costs 120 €/MWh and the final price of iron is €200, -; then:

$$a_{ij} = \frac{120 * 60}{200 * 120} = \frac{120}{200} * 0.5 = 0.3$$

Physical Input-Output Tables (PIOT)

(measures in ton, MWh, km, …)

	A. INTERMEDIATE FLOWS (Z)					B. FINAL DEMAND (f)					
	Agriculture 1	Manufacturing 2	Transportation 3	Service 4	Total interm. flows	Private consumption	Public consumption	Investments	Stock	Exports	TOTAL OUTPUT
1 Agriculture	z_{11}	z_{12}	z_{13}	z_{14}	$\Sigma_j z_{1j}$	c_1	g_1	u_1	vs_1	e_1	x_1
2 Manufacturing	z_{21}	z_{22}	z_{23}	z_{24}	$\Sigma_j z_{2j}$	c_2	g_2	u_2	vs_2	e_2	x_2
3 Transportation	z_{31}	z_{32}	z_{33}	z_{34}	$\Sigma_j z_{3j}$	c_3	g_3	u_3	vs_3	e_3	x_3
4 Service	z_{41}	z_{42}	z_{43}	z_{44}	$\Sigma_j z_{4j}$	c_4	g_4	u_4	vs_4	e_4	x_4
	C. LABOUR										
Labour	l_1	l_2	l_3	l_4	$\Sigma_j l_j$						
	D. RESOURCES FROM OUT OF THE SYSTEM										
Imports	m_1	m_2	m_3	m_4	$\Sigma_j m_j$						
Primary resources	r_1	r_2	r_3	r_4	$\Sigma_j r_j$						

Monetary Input-Output Tables (MIOT)

Values in euro or other currencies, but always one currency for the whole table)

	A. INTERMEDIATE FLOWS (Z')					B. FINAL DEMAND (f')					
	Agriculture 1	Manufacturing 2	Transportation 3	Service 4	Total interm flows	Private consumption	Public consumption	Investments	Stock	Exports	TOTAL OUTPUT
1 Agriculture	z'_{11}	z'_{12}	z'_{13}	z'_{14}	$\Sigma_j z'_{1j}$	c'_1	g'_1	u'_1	vs'_1	e'_1	x'_1
2 Manufacturing	z'_{21}	z'_{22}	z'_{23}	z'_{24}	$\Sigma_j z'_{2j}$	c'_2	g'_2	u'_2	vs'_2	e'_2	x'_2
3 Transportation	z'_{31}	z'_{32}	z'_{33}	z'_{34}	$\Sigma_j z'_{3j}$	c'_3	g'_3	u'_3	vs'_3	e'_3	x'_3
4 Service	z'_{41}	z'_{42}	z'_{43}	z'_{44}	$\Sigma_j z'_{4j}$	c'_4	g'_4	u'_4	vs'_4	e'_4	x'_4
Total interm. flows	$\Sigma_i z'_{i1}$	$\Sigma_i z'_{i2}$	$\Sigma_i z'_{i3}$	$\Sigma_i z'_{i4}$	$\Sigma_{ij} z'_{ij}$	$\Sigma_j c'_j$	$\Sigma_j g'_j$	$\Sigma_j u'_j$	$\Sigma_j vs'_j$	$\Sigma_j e'_j$	$\Sigma_i x'_i$
	C. VALUE-ADDED										
Wages	v'_{11}	v'_{12}	v'_{13}	v'_{14}	$\Sigma_j v'_{1j}$						
Profit etc.	v'_{21}	v'_{22}	v'_{23}	v'_{24}	$\Sigma_j v'_{2j}$						
Total value-added	$\Sigma_i v'_{i1}$	$\Sigma_i v'_{i2}$	$\Sigma_i v'_{i3}$	$\Sigma_i v'_{i4}$	$\Sigma_{ij} v'_{ij}$						
	D. RESOURCES FROM OUT OF THE SYSTEM										
Imports	m'_1	m'_2	m'_3	m'_4	$\Sigma_j m'_j$						
Primary resources	r'_1	r'_2	r'_3	r'_4	$\Sigma_j r'_j$						
	E. TAXES										
Taxes	t'_1	t'_2	t'_3	t'_4	$\Sigma_j t'_j$						
Total output	x'_1	x'_2	x'_3	x'_4	$\Sigma_i x'_i$						

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The intermediate flows between the sectors are given by the **z-matrix**. The final demand is considered to be one vector.

In the MIOT the rows represent the income and the columns represent the costs.

Data and variables for input-output model (physical)

* n = number of sectors.

* $\boldsymbol{z_0}$ = **intermediate flows matrix** (n×n).
* $\boldsymbol{z_{ij}}$ = element of $\boldsymbol{z_0}$ matrix denoting the total physical flow from sector i to sector j.
* $\boldsymbol{f_0}$ = **final demand vector** (n×1).
* $\boldsymbol{f_i}$ = element of $\boldsymbol{f_0}$ vector denoting the final demand of sector i (as quantity).
* $\boldsymbol{A}$ = **technical coefficients matrix** (n×n).
* $\boldsymbol{a_{ij}}$ = element of matrix **A** denoting the required main output quantity of sector i to produce one unit of main output of sector j.
* $\boldsymbol{x_0}$ = **total output vector** (n×1).
* $\boldsymbol{x_i}$ = element of vector $\boldsymbol{x_0}$ denoting the total output produced by sector i (as quantity).

Identities

* $\boldsymbol{x_i = \sum_j z_{ij} + f_i}$
* $\boldsymbol{a_{ij} = \frac{z_{ij}}{x_j}}$
* $\boldsymbol{z_{ij} = a_{ij} * x_j}$

$$\boldsymbol{x_0} = \begin{bmatrix} \boldsymbol{x_1} \\ \boldsymbol{x_2} \\ \dots \\ \boldsymbol{x_n} \end{bmatrix};\ \boldsymbol{f_0} = \begin{bmatrix} \boldsymbol{f_1} \\ \boldsymbol{f_2} \\ \dots \\ \boldsymbol{f_n} \end{bmatrix};\ \boldsymbol{A} = \begin{bmatrix} \boldsymbol{a_{11}} & \boldsymbol{a_{12}} & \dots & \boldsymbol{a_{1n}} \\ \boldsymbol{a_{21}} & \boldsymbol{a_{22}} & \dots & \boldsymbol{a_{2n}} \\ \dots & \dots & \dots & \dots \\ \boldsymbol{a_{n1}} & \boldsymbol{a_{n2}} & \dots & \boldsymbol{a_{nm}} \end{bmatrix}; \boldsymbol{I} = \begin{bmatrix} \mathbf{1} & \mathbf{0} & \dots & \mathbf{0} \\ \mathbf{0} & \mathbf{1} & \dots & \mathbf{0} \\ \dots & \dots & \dots & \dots \\ \mathbf{0} & \mathbf{0} & \dots & \mathbf{1} \end{bmatrix}$$

* $\boldsymbol{x_0 = Ax_0 + f_0}$
* $(\boldsymbol{I - A})\boldsymbol{x_0 = f_0}$
* $AA^{-1} = I$
* $(\boldsymbol{I - A})^{-1}(\boldsymbol{I - A})\boldsymbol{x_0} = (\boldsymbol{I - A})^{-1}\boldsymbol{f_0}$
* $(I - A)^{-1}(I - A) = I$
* $Ix_0 = x_0$
* $\boldsymbol{x_0} = (\boldsymbol{I - A})^{-1}\boldsymbol{f_0}$
* $(\boldsymbol{I - A})^{-1} = \boldsymbol{B}$
* $\boldsymbol{x_0 = Bf_0}$

$(\boldsymbol{I - A})^{-1}$ is referred to as **Leontief's inverse**. The **Leontief inverse coefficient, $\boldsymbol{b_{ij}}$**, represents the direct, indirect, and induced requirements from sector i to produce one unit of final demand of sector j. This coefficient gives us the idea how strongly or weakly dependent sectors j and i are.

* $\boldsymbol{x'_j = p_j * x_j}$
* $\boldsymbol{z'_{ij} = p_i * z_{ij}}$
* $\boldsymbol{f'_j = p_j * f_j}$
* $\boldsymbol{a'_{ij} = \frac{z'_{ij}}{x'_j} = \frac{p_i * z_{ij}}{p_j * x_j} = \left(\frac{p_i}{p_j}\right) * a_{ij}}$

After obtaining the monetary technical coefficient a'_{ij} all the equations related to physical flows become valid also for monetary flows.

Data and variables for input-output model (monetary)

* $\boldsymbol{n} =$ number of sectors.
* $\boldsymbol{z'_0} =$ **monetary intermediate flows matrix** (n×n).
* $\boldsymbol{z'_{ij}} =$ element of $\boldsymbol{z'_0}$ matrix denoting the total monetary flow from sector i to sector j.
* $\boldsymbol{f'_0} =$ **final demand vector** (n×1) (as value).
* $\boldsymbol{f'_i} =$ element of $\boldsymbol{f'_0}$ vector denoting the final demand of sector i (as value).
* $\boldsymbol{A'} =$ **technical monetary coefficients matrix** (n×n).
* $\boldsymbol{a'_{ij}} =$ element of matrix **A'** denoting the value of required main output of sector i to produce the main output of sector j having 1-euro value.
* $\boldsymbol{x'_0} =$ **total output vector** (n×1) (as value).
* $\boldsymbol{x'_i} =$ element of vector $\boldsymbol{x'_0}$ denoting the total output produced by sector i (as value).

When the total demand (f_o) of one sector increases, then the total output (x_0) for all the sectors increases as well. This increase will not be equal to the increase in total demand. Other changes, like changes in technology, affect the total output vector as well.

The general input-output model can be used on different levels, such as:

* World
* National (national accounts)
* Regional (regional input-output analysis)
* Interregional (multiregional input-output analysis)

Enterprise input-output models

Enterprise input-output model units:

* A network of firms/supply chains – firms, productions processes
* Industrial districts – firms, production processes
* Production chain of a single firm – production processes

An **Enterprise Input-Output (EIO) model** can be used as various things, such as an Accounting tool, Planning tool, Sustainability analysis, etc.

An EIO as **accounting tool** is used for:

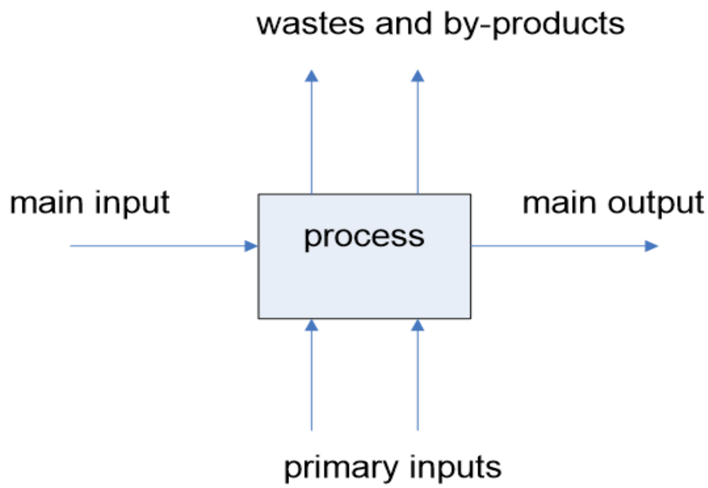
* Analysis of the materials and monetary flows between the units of the network.
* Evaluation of the energy input mix of production units.
* Monitoring the wastes emissions.

An EIO as **planning tool** is used for:

* Material flows evaluation for a new final demand.
* Analysis of new sustainable solutions.
* Etc.

Representation of a production process

See the following picture.



When such production processes are linked together, a supply chain flow diagram will be formed. The main output of one process will become the main input for another process.

Components of flow diagrams

* **Primary input** of a production process are only those inputs that are not provided by one of the production processes of a supply chain, such as raw materials, natural resources, and energy resources.
* The **main outputs** are the outputs resulting from a manufacturing process which is the primary focus of production. Through supply chain flows, main outputs of a process can become the **main input** of another process.
* **Secondary outputs** generally refers to two terms: **Wastes** that has no perceived economic value an that traditionally is to be discarded, and **By-product** that has perceived economic value that can be reused, recycles, or recovered.

EIO data and variables (physical)

* $\boldsymbol{n}$ = number of sectors.
* $\boldsymbol{z_0}$ = **intermediate flows matrix** (n×n).
* $\boldsymbol{z_{ij}}$ = element of $\boldsymbol{z_0}$ matrix denoting the total physical flow from sector i to sector j.
* $\boldsymbol{f_0}$ = **final demand vector** (n×1).
* $\boldsymbol{f_i}$ = element of $\boldsymbol{f_0}$ vector denoting the final demand of main output i (as quantity).
* $\boldsymbol{A}$ = **technical coefficients matrix** (n×n).
* $\boldsymbol{a_{ij}}$ = element of matrix **A** denoting the required main output quantity of process i to produce one unit of main output of process j.
* $\boldsymbol{x_0}$ = **total output vector** (n×1).
* $\boldsymbol{x_i}$ = element of vector $\boldsymbol{x_0}$ denoting the total output produced by process i (as quantity).

* $\boldsymbol{s}$ = **number of primary inputs** $(k = 1, 2, \dots, s)$
* $\boldsymbol{m}$ = **number of wastes and by-products** $(l = 1, 2, \dots, m)$
* $\boldsymbol{R}$ = **primary inputs coefficients matrix** (s×n)
* $\boldsymbol{r_{kj}}$ = element of matrix **R** denoting the quantity of primary input k required to produce one unit of main output j.
* $\boldsymbol{r_0}$ = **total primary input use vector** (s×1)
* $\boldsymbol{r_k}$ = element of vector $\boldsymbol{r_0}$ denoting the use of primary input k in all processes.

* $\boldsymbol{W}$ = **waste and by-products matrix** (m×n)
* $\boldsymbol{w_{ij}}$ = element of matrix **W** denoting the quantity of waste or by-product l emitted by the production of one unit of main output j
* $\boldsymbol{w_0}$ = **total wastes and by-product emission vector** (m×1)
* $\boldsymbol{w_l}$ = element of vector $\boldsymbol{w_0}$ denoting the total quantity of waste or by-product l emitted by all processes

EIO identities

* $\boldsymbol{x_0 = (I - A)^{-1} f_0}$
* $\boldsymbol{r_0 = R x_0}$
* $\boldsymbol{w_0 = W x_0}$
* Assumption $\boldsymbol{z_{ii} = 0}$

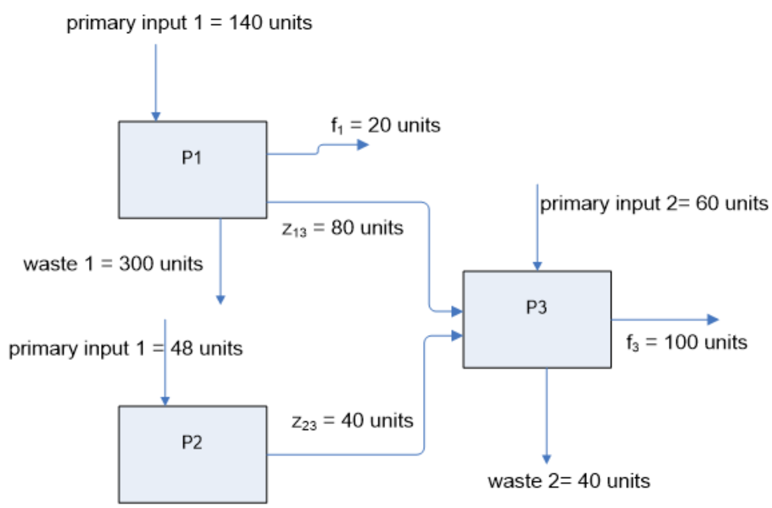
Waste and by-products are not included within the total output vector, x_0.

* To compute the **coefficients of the technical coefficient matrix (A),** the intermediate flows (z_{ij}) are divided by the total output (x_j) of the final process in the supply chain.
* To compute the **coefficients of the primary inputs coefficients matrix (R),** the values of the total primary input use vector (r_0) are divided by the total output (x_i) of the corresponding process.
* To compute the **coefficients of the waste and by-products matrix (W),** the values of the total waste and by-product emission vector (w_0) are divided by the total output (x_i) of the corresponding process.

The difference between several primary inputs is the typology of the input. The primary inputs are categorized on typology. This is the same for the wastes and by-products.

Example:

EIO model



Input-output table

Processes	P_1	P_2	P_3	f_0	x_0
P_1			80	20	100

P_2			40		40
P_3				100	100
Primary inputs					
Primary input 1	140	48		188	
Primary input 2			60	60	
Wastes and by-products					
Waste 1	300			300	
Waste 2			40	40	

How to calculate coefficients

Processes	P_1	P_2	P_3	f_0	x_0	
P_1			80/100	20	100	
P_2			40/100		40	
P_3				100	100	
Primary inputs						A
Primary input 1	140/100	48/40		188		
Primary input 2			60/100	60		
Wastes and by-products						R
Waste 1	300/100			300		
Waste 2			40/100	40		W

$$A = \begin{bmatrix} 0 & 0 & 80/100 \\ 0 & 0 & 40/100 \\ 0 & 0 & 0 \end{bmatrix} = \begin{bmatrix} 0 & 0 & 0.8 \\ 0 & 0 & 0.4 \\ 0 & 0 & 0 \end{bmatrix}$$

$$R = \begin{bmatrix} 140/100 & 48/40 & 0 \\ 0 & 0 & 60/100 \end{bmatrix} = \begin{bmatrix} 1.4 & 0.48 & 0 \\ 0 & 0 & 0.6 \end{bmatrix}$$

$$W = \begin{bmatrix} 300/100 & 0 & 0 \\ 0 & 0 & 40/100 \end{bmatrix} = \begin{bmatrix} 3.0 & 0 & 0 \\ 0 & 0 & 0.4 \end{bmatrix}$$

Paper Design for Sustainability: Current trends in sustainable product design and development

The **Design for Sustainability (D4S)** concept outlines methodologies for making sustainable improvements to products by applying elements of life cycle thinking. D4S build on the work of eco-design to include economic and social concerns, and its methodology includes both incremental and radical innovation. D4S is a unique methodology because it not only encompasses all three pillars of sustainability (people, planet, and profit), but it also is applicable to supporting sustainable production capacity in developing countries.

D4S is an eco-design concept that has evolved to include both the social and economic elements of production. It integrates the three pillars of sustainability but goes beyond simply “greening” products to embrace how to meet consumer needs in a more holistic, sustainable way.

These newly designed products and services offer increased functionality and ease of use, longer life spans, easy disassembly or recyclability, lower environmental impact which can save the company money, and improved materials sourcing and production which can positively affect communities.

Product innovation is instrumental for economic growth. Successful innovation is the driver of competitive advantage and, along with sustainability, forms the core of the D4S methodology. D4S is designed to include a wide range of approaches that can be tailored and applied to improve the efficiency and social qualities of products, services, and systems.

The key D4S approaches are redesign and benchmarking, and new product design and PSS (Product-Service Systems.

Summary 2: Production 1

Materials

A **material** consists of elementary particles, which directly drive what is possible in production (some materials are suitable only for some processes).

The elementary particles of each material are different. All materials consists of atoms. Properties of material are determined by:

1. Type of atoms.
2. Type of connection between the atoms.

Putting atoms together does not necessarily generate a material. Not every set of atoms is a material. There are two types of connections between atoms:

1. **Atomic structure**, atoms cluster with atoms of the same type. (e.g. **metals**)
2. **Molecule structure**, atoms connect to other (different) atoms. (e.g. **plastics**)

Structures of metal

Metals have a crystal structure. Atoms attempt to fill space as effectively as possible. Different types of atoms attempt that in different ways, so they will have a different structure. A different structure will result in a different behavior. Sometimes, the structure of the material depends on the temperature. The atoms will try to find the most energetic optimal spot. The different structures can be found in figure 3.

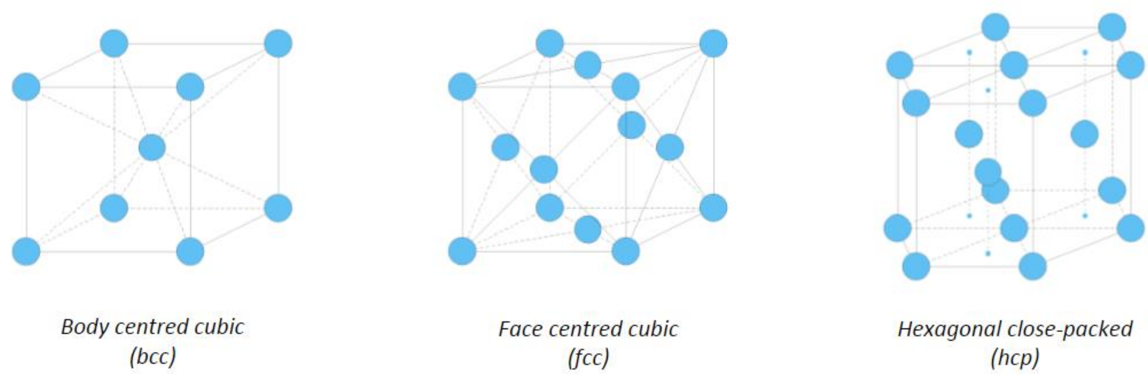


Figure 1: Different material structures

The body centric cubic (BBC) the body centered cubic can be seen as multiple layers of atoms. It has one atom in the middle, that connects the layers of atoms. The middle atom is part of the second layer.

Face centered cubic (FCC) The face centered cubic consists of atoms at each corner, and atoms in the middle of each plane.

Hexagonal close-packed (HCP) The hexagonal close-packed structure is a lot more complicated. It is difficult to form, and difficult to machine.

Metal crystal and behavior

A **crystal structure** emerges from atoms connecting to other atoms mostly of the same type. Most metals consists of many little crystals. The crystals are oriented randomly. As soon as we solidify molten metal, than the we will start building grains. If you cool down fast, than the material will not have time to grow big crystals. If you force the metal to cool down quickly, than the crystals will be many, but small. If you cool down material slowly, the crystals will be bigger.

The smaller the crystals, the more grains, the stronger your material so forcing material to cool down fast could pay off. With slow cooling down, segregation could be a risk. Different types of material with different types of melting temperatures will segregate.

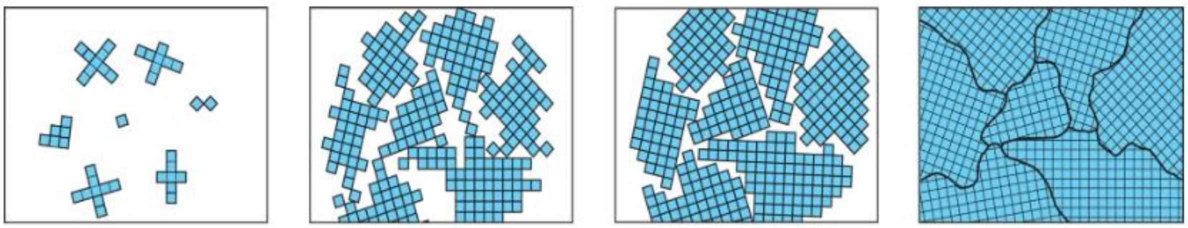


Figure 2: Cooling down of metal

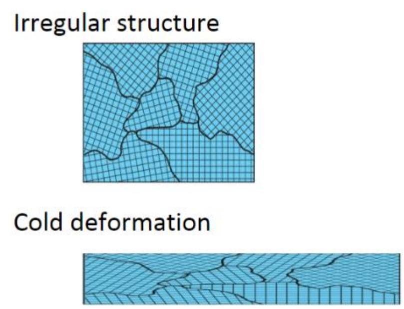


Figure 3: Anisotropic behaviour

Atoms could be unstructured in specific places as can be seen in figure 4. The more of those borders, the harder it is to make a material. It is called an Irregular structure. The differences of light reflection can show the different crystals.

The more crystals, the more difficult it will be to deform the material. If we will be deforming the material in a cold way (flatten it), than the grains will be deformed. The crystals will be having a different shape. In cold deformation, the material will get crystals in more or less the same direction. That is because the atoms doesn't crystalize when it is cold.

This way of cold deformation is called ***anisotropic behavior***: value of material properties changes with the direction of the measurement. This causes the effect that measurement can be different if we measure it in different directions. The material behavior will change with the direction in which you measure it.

Exam Alert!

Plastics

In general: ***plastics = polymer + addition***. It is sometimes compared with spaghetti, also very long and it will stick together after cooling down.

There can be several additions that you can add to the polymers. Different additions will cause different behaviors. Think of a cheaper filler (polymers are expensive), or additions that will improve mechanical properties (make it harder) or process ability (change the viscous temperature of the material).

There are a few main groups of plastics:

- **Thermoplastic material**, if you heat up a peace of plastic, it will become viscous, and you can deform if.

- **Elastomers**. Rubbery material, combination of thermoplastic and thermosetting material.
- **Thermosetting material**, if you heat up this kind of plastic, it will disintegrate.
- **Co-polymer**. One type of macro-molecule from different monomers.
- **Poly-blends**. Different types of macro-molecules.

The type of plastic does not say anything about its strength, hardness, etcetera. The only differences is the substance when heating up.

Casting

General

Casting is turning raw material into a usable block of material for the first time, so giving shape to raw material for the first time. The type of raw material we start with is quite determinative for the production process. For each material type, there are different types of production process.

- Liquid -> **Casting**. Pour the molten material into a mold, and let it cool down.
- Viscous -> **Plastic processing**. A lot of pressure will be needed.
- Powder -> **Powder metallurgy** (sintering). This is done with materials with a very high melting point. We start with powder, push it really hard together, then bake.

There are different types of molds that can be used in the casting process:

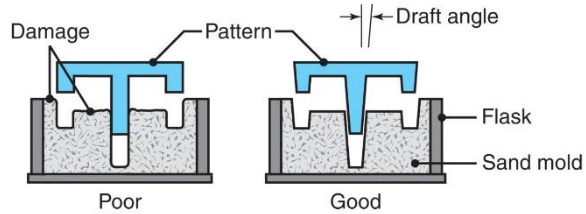
1. **Expendable molds**. These molds are made of sand or ceramics. The mold will be damaged in the process and has to be made over and over for every product. It can be used in:
   - Sand casting.
   - Shell molding.
   - Investment casting.
2. **Permanent molds**. These molds are made from metal. It is mostly used for products that are needed in large quantities (sometimes >3000). It is essential that these mold is designed in such a way that the product can be removed without damaging the mold. It can be used in:
   - Permanent-mold casting.
   - Die casting.
   - Centrifugal casting.
3. **Composite molds**. A combination of expandable and permanent molds.

Metal casting

It could be a dangerous process, but it is needed in many cases. There are several advantages:

1. **Complex shapes can be made.**
2. **Large products in one piece.**
3. **Mostly cheap**. There are possibilities for mass production as well for small quantities.
4. **Isotropic final product**.
5. **Economic batch size**. Casting processes can be used to make single peaces (church clock) to hunders of thousends (pencil).

If you start lifting the product out of the mold, there is a possibility that there will be a vacuum. There is a big risk that the mold will be damaged, therefore we will use a **draft angle**, to pull out the pattern in an angle. In this case we will not create a vacuum, so the mold will not be damaged.



Shrinkage

The volume of the metal decreases as it cools down, so a bit more has to be poured in the mold in case extra material is needed. Through shrinking of the material, the measures of a wooden model differ from those on the construction drawing. Special rulers are being used.

EXAM QUESTION: What would be the true size of 1000 mm on a special ruler for aluminum? (aluminum has a volumetric shrinkage of 6,6 percent).

- It is important to know that we are always talking about volumetric shrinkage.
- Material will always shrink in three directions.
- So l * w* h -6,6% = 1m^3.
- We will assume that the cube has equal lengths in width, height, and length. So l = W = H = Y.
- So: $y^3 - 0.066 * Y^3 = 1$ ->
- $y^3 *(1-0066) = 1$ gives
- y = 1.023 mm.
- So 1.000 mm on the ruler for aluminum is 1.023.

Exam Alert!

Defects

There are different defects in casting:

- **Cavities**: The mold is initially filled with air and we have to push it out to escape, but it is trapped inside. Cavities can be blowholes (large spherical holes near the surfaces) or shrinkage cavities (pipe at the top caused by shrinkage during the solidification).
- **Discontinuities**: if we have very complex products, the material might be poured from two sides. There might not be complete fusion. Several things could occur:
  - **Cracks**. Caused by a temperature difference between the metal poured from two sides.
  - **Cold and hot tears.** In hot tearing, course grain size and the presence of low-melting-point segregates along the grain boundaries. (hot tearing: partly liquid partly solid, cold is all solid)
  - **Cold shut.** Interference in a casting because the metal was poured from two sides.
- **Incorrect dimensions**: Occur by the shrinkage of the material after the casting.
- **Inconclusions**. Reduction in the strength of the material caused by the way of casting.

Expendable Molds

Expendable molds are used a lot in sand casting (limited to metals). There are a number of advantages and drawbacks of sand casting:

1. No limit to size, weight or shape.
2. Low tooling cost.
3. Hardly a limitation of metal.
4. Product geometry. All kinds of curved shapes; large products.
5. Relatively course surface finish.
6. **Accuracy is not very high.**

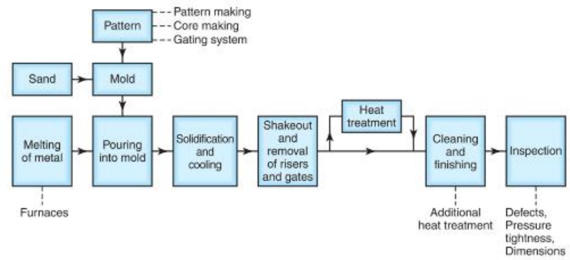


Figure 4: Process of Sand Casting

Note that sand casting will not work for plastic, because the plastic will stick to the sand. The sand cannot be any sand, there are several types of sand that can be used (**naturally/synthetic bonded sand, and silica sand**).

The soon as you have a design, there is a large probability that you will simulate to test if sand casting is possible. At the highest point of the mold, there should always be a riser, or an air opening where air can escape, otherwise you will have air bubbles. You will also need floating pins, otherwise there is a possibility that the sand starts floating on the metal.

In the end, we are only interested in the blue part (figure 7). ***The risers are used for prevention of shrinkage***. The vent is used for the prevention of air bubbles.

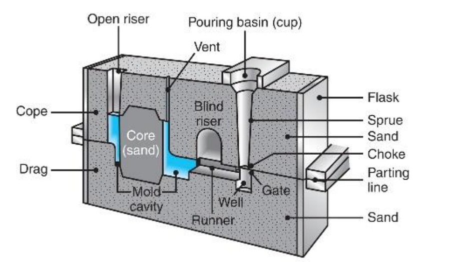


Figure 5: Sand Casting Method

Hollow regions can be formed by ***internal cores***. The use of a sand core will not give you an extremely precise product. Often, after machinery is used to make the right product. External cores are used with big or complex models to form features. Sometimes, it is necessary to make the product possible.

In every product that is made with sand casting, you will see the ***parting line***. ***The product will not be very shiny, that has to do with the roughness of the sand***.

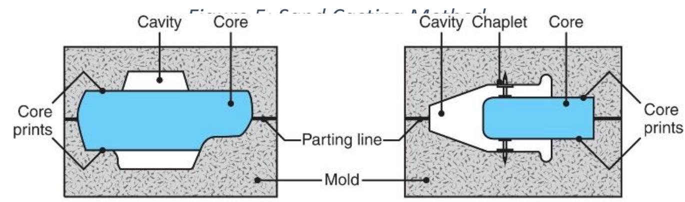


Figure 6: Sand casting with cores and parting lines

Shell molding

Because sand casting is not very accurate, people have been searching for a different way, namely *shell molding*. Shell molding has several advantages and drawbacks:

1. High accuracy. Positioning holes are possible.
2. **High production rate.**
3. Limited part size. Complex process which takes a lot of handling.
4. Product geometry. Smooth surfaces, acute angles, thin walls.
5. **Expensive equipment.**
6. Mold material. Coated sand, hardened in the oven.

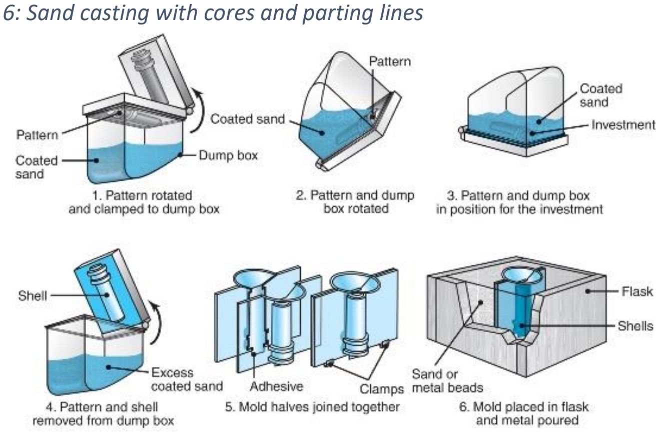


Figure 7: Shell moulding process

The product geometry consists of smooth surface, acute angles, and the possibility of a mold with thin walls. The mold material is coated sand, hardened in the oven. Therefore it could have a higher accuracy.

The pattern is in the case of shell molding not made of wood, but made of metal. This makes it more expensive, but the **pattern can also be reused**.

Investment casting

In case of investment casting, you do not even lose your mold, but you also lose your pattern. The mold material consists of ceramics rather than sand. It is a very complex process that takes a lot of handling. There is also expensive materials and labor. The molds are made out of ceramics. The project geometry is characterized by:

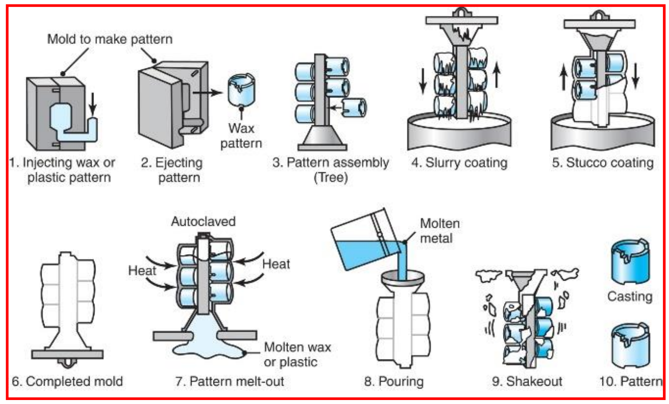


Figure 8: Process of Investment casting

1. Smooth surfaces.
2. There is no draft angle needed. Since the mold will be destroyed anyway.
3. We usually make only small products, because of the complexity.

The product material that will come out could almost be any material, but mainly metals.

Permanent Molds

Permanent molds are molds that can be used to produce more then one product. When using permanent molds, many products are made with one mold. It is only possible for shapes that 'release', so ***undercuts are impossible***. Draft angles are really essential to prevent mold wear. The **lead time will be long** because it takes time to prepare the mold.

Because the molds can be made out of metal, we can have a good surface finish and a high accuracy. Unfortunately, there is a limited part complexity because there is a lot of contact between the product and the metal. If parts are to complex, it will be too difficult to remove parts from the mold.

The mold material is always metal, and sometimes you could use a sand core, but usually we stick to metal. The product geometry:

Figure 9: Ejector pins in permanent mould casting

- smooth surface
- simple products
- draft angle
- use different metals for cast and product. Therefore, the product material is mostly nonferrous metal or cast iron.

Ejectors are used a lot, because it is possible that the cooled down molten metal will stick to the mold. That is only possible if the product is hard enough. ***Ejector pins are good indicitation that product was made with permanent mould casting.***

Pressure die casting

Permanent mold casting can be done with some pressure. It has high dimensional accuracy, a very good surface finish, high production rate but also a long lead time and high die costs.

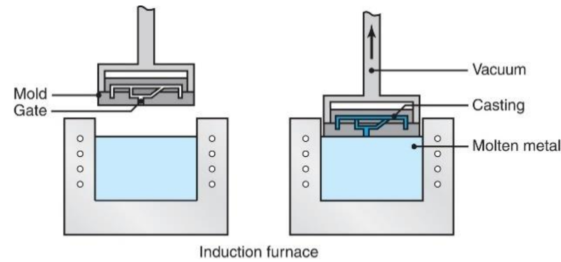


Figure 10: Vacuum casting

The mold material consists of metal, and a metal core (because of the pressure, a sand core would be damaged by the pressure). The product geometry has a limited size, can consist of thin walls, and are nonferrous metals.

Vacuum casting

In vacuum casting, the mold will be pushed in the molten metal. It will create a vacuum on top, which means that we can fill the entire mold. This is useful for products where you do not want air bubbles.

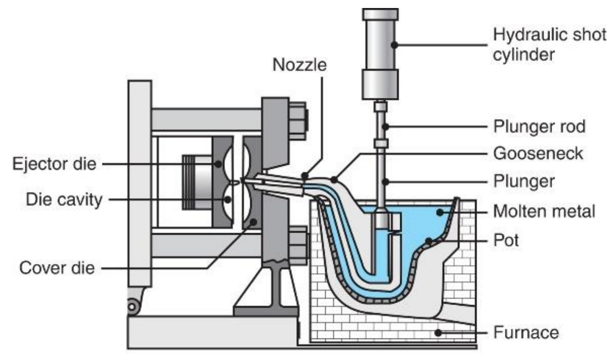


Figure 11: High pressure die casting (Hot Chamber)

High pressure die casting

High pressure die casting comes in two forms. *Hot chamber and cold chamber.*

In ***hot chamber*** die casting, there are two dies pushed together. The furnace is immediately connected to the moulds. A plunger goes up so that the material can flow into the machine, then the plunger goes down and closes the entrance by pushing down, thus it increases the pressure in the machine, thus the material is pushed into the mould with high pressure, when it cools down the product it is pushed out by the ejector pins. The characteristics are:

1. Oven is part of the machine.
2. 3-30 MPa pressure.
3. Cooling by water or oil. The mold becomes expensive, but the production goes at a higher rate.

In **cold chamber** die casting, the metal is pushed into a horizontal cylinder, the plunger pushes to the left and the material fills the mold. There are quite some mechanisms involved to clamp the molds together. The force required to resist the pressure is very high. The characteristics are:

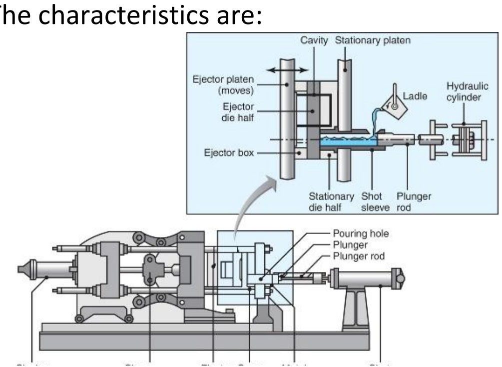


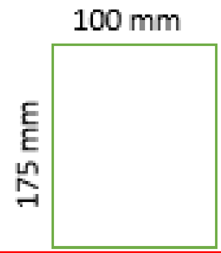
Figure 12: High pressure die casting (cold chamber)

1. Oven is outside the machine.
2. 70-200 MPa pressure.
3. More then 70% of the machine consists of the mechanism that closes the dye.

It is also possible to work with plastics, but that is a bit harder. Plastic will never become a liquid. When working with plastics, it is important to take into account the velocity of the die, and the speed of cooling down.

Assignment

Exam Alert!



Estimate the clamping force for this rectangle hot chamber die-casting machine (15MPa). The projections are = 100 * 175 = 17,500 mm^2. The pressure is 15MPa, so the clamping force = 15*17,5 = 263kN. For a cold chamber process, the answer would be different because of the higher pressure

Rotational molding

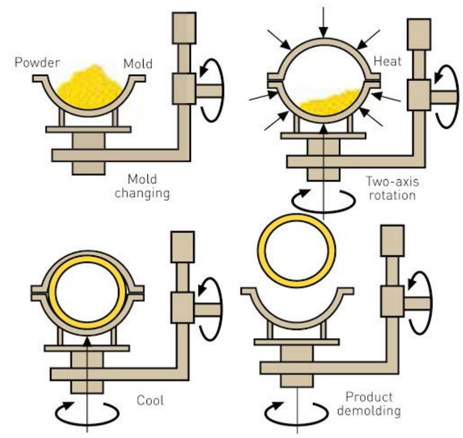


Figure 13: Rotational moulding process

Exam Alert!

In ***rotational molding***, the machine is turning into unpredictable ways, the small granulated pellets start melting and become viscous. As soon as they melt they will stick to the walls of the mold and slowly form the outside of the product. The rest of the gravel will be dispersed randomly to form the inside of the wall. Rotational molding has several characteristics:

1. **Moderate production rate**. The molding system is not too fast, but is automated.
2. **Relatively cheap molds**. The molds are made of many thin components. It is relatively easy and cheap to make.
3. **Product geometry**. Hollow parts and complex products are possible.
4. **Product material**. Foremost plastics.
5. **Mold material**. Thin metal.
6. **Significant infrastructure required**. We will need a big furnace.
7. **Molds can consist of multiple parts**. We are not relying on two parts of the mold opening and closing, but on more parts which can produce more complex products.

If you see a hollow product, and there is no clear part taken out of the product (especially in plastics) then you are 99% sure that it is rotational molding. A drawback of rotational molding is that the thickness of the walls is not everywhere the same, and the unpredictable structure of the inside of the product.

(Semi-)Centrifugal Casting

Centrifugal casting is in fact a faster way of rotational casting. The rotational speed increases which means a **higher production rate, expensive equipment and a limited part shape** (because the mold has to rotate fast). In this case the mold material is made of metal or graphite.

The product geometry consist of **hollow, cylindrical parts**. The product material is non-ferrous and ferrous metals and alloys. The melting temperature cannot be very high.

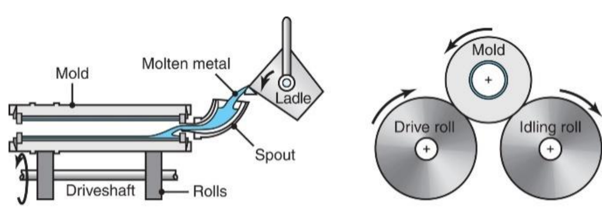


Figure 14: Semi-centrifugal casting

Centrifugal casting

Centrifugal casting rotates faster then semi-centrifugal casting. It is typically used for products with **higher quality surface finish** requirements, so on the outside rather then on the inside. For centrifugal and semi-centrifugal casting, the products have to be **rotational symmetric**. You will **not see parting lines** very clearly.

Design Rules

In case of casting, there are a number of rules to help the designer to convey the idea of the consumer to a nice mold.

Rule 1: Adjust the design to the **most simple casting process**.

Rule 2: Avoid accumulation of metal. Cooling down will go slower when there is an accumulation of material, it happens a lot in corners of the products. It can easily be avoided by a **constant wall edges, and without corners.**

Rule 3: Avoid large flat areas, use rib.

Rule 4: Adjust a draft.

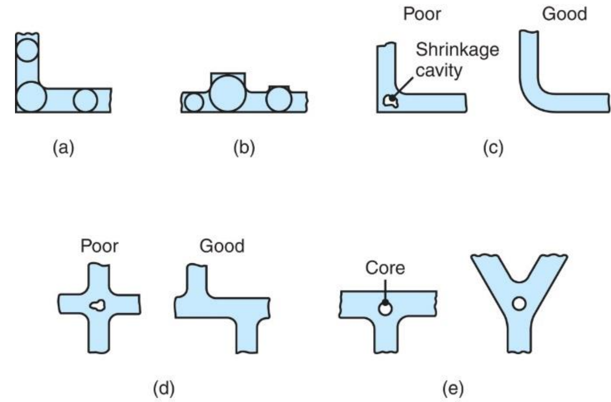


Figure 15: Some important drawing rules practiced

The choice of the right process is based on technical possibilities and limitations, these limitations depends on several factors:

1. Product material.
2. Product geometry.
3. Product size.
4. Product complexity.
5. Dimension accuracy.
6. Quality of surface finish.
7. Level of detail.

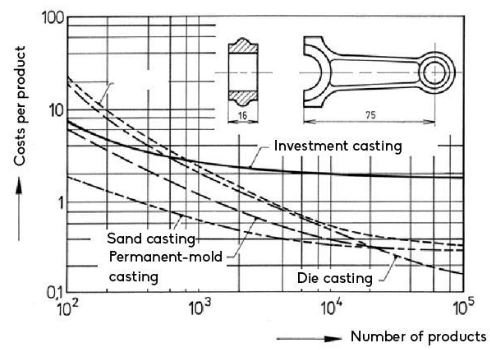


Figure 16: Graph of manufacturing costs

The manufacturing costs are also important. The manufacturing costs will depend on:

1. Equipment costs.
2. Labor costs.
3. Production rate.
4. Initial period.

As a designer, you will have to be able to identify the casting method based on several things:

1. **Locating parting line**. If there is a really clear parting land, sand or shell casting. If it is thin, but very explicit, then permanent mold casting. If there is more then 1 parting line, probably rotational molding.
2. **Locate ejection point**.
3. **Choose runner.**
4. **Locate sprues and risers**.
5. **Required finishing**.

Summary

Summary of Casting Processes

Process	Advantages	Limitations
Sand	Almost any metal can be cast; no limit to part size, shape, or weight; low tooling cost	Some finishing required; relatively coarse surface finish; wide tolerances
Shell mold	Good dimensional accuracy and surface finish; high production rate	Part size limited; expensive patterns and equipment
Evaporative pattern	Most metals can be cast, with no limit to size; complex part shapes	Patterns have low strength and can be costly for low quantities
Plaster mold	Intricate part shapes; good dimensional accuracy and surface finish; low porosity	Limited to nonferrous metals; limited part size and volume of production; mold-making time relatively long
Ceramic mold	Intricate part shapes; close-tolerance parts; good surface finish; low cooling rate	Limited part size
Investment	Intricate part shapes; excellent surface finish and accuracy; almost any metal can be cast	Part size limited; expensive patterns, molds, and labor
Permanent mold	Good surface finish and dimensional accuracy; low porosity; high production rate	High mold cost; limited part shape and complexity; not suitable for high-melting-point metals
Die	Excellent dimensional accuracy and surface finish; high production rate	High die cost; limited part size; generally limited to nonferrous metals; long lead time
Centrifugal	Large cylindrical or tubular parts with good quality; high production rate	Expensive equipment; limited part shape

Shaping

3D deformation

There are several types of deformation (hot vs. cold):

Hot

- Recrystallization.
- Improved structure.
- $0.7 * T_m < T < 0.8 * T_M$
- Lot of energy used
- Less force needed to deform

Warm

- No crystallization
- Lower yield strength
- $0.3 * T_m < T < 0.4 * T_M$
- Easier deformation

Cold

- No crystallization -> anisotropic
- Work-hardening.

The stress strain curve shows the strain (deformation) for a specific amount of stress. In the first part, the change is linear, and the material will have an elastic behavior. If the stress is released, the material will go back to its original shape. In general, we will work between the yield point (Y) and the tensile strength (UTS).

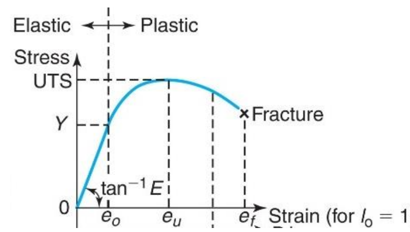


Figure 17: Stress Stain curve

By deforming the product, the product will **become stronger (especially in cold deformation).** More force will be needed to deform it another time.

Forging

Forging is taking a piece of material (possibly warmed up) and apply forces. It is shaping by the application of compressive forces. In any case, there are high equipment and labor costs. People have to be very skilled, and machines are complicated. In forging, we can achieve high **strength/toughness** materials.

It is possible to make complex shapes and you can make very small up to very large products. Forging is usually done in batches.

Cold forging

- Good surface finish and accuracy
- Crystal deformation
- A lot of force needed

Hot forging

- Lower forces required
- Worse surface finish and accuracy.
- Strengthening.

Open-die forging can be sued for limited shapes (it is difficult to make complex shapes), small quantities (because everything is done by hand) and mostly hot forging (to reduce the amount of forces).

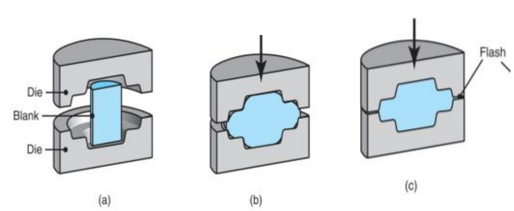


Figure 18: Closed-die forging

Closed-die forging can be sued for complex shapes and larger quantities. The mold will be more expensive because the die will have the shape information that we need. The dies will hardly every completely close. It will leave a **parting line and flash**.

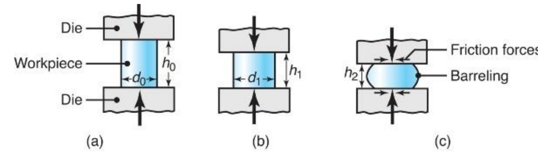


Figure 19: Open-die forging

These processes need different steps. There are five typical steps that are needed in forging:

1. Blank (bar stock);
2. Edging, more or less shape in the right way;
3. Blocking, first step of forging, you will see flash;
4. Finishing, second step of forging (only last part of deformation;
5. Trimming, trip away the flash.

Heading = changing the shape in a number of steps, each step gets closer to the shape we want.

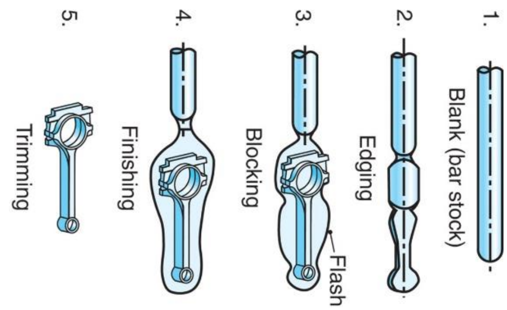


Figure 20: Five steps of forging

Coining = a process with high accuracy and surface finish. We do not have any flash in coining.

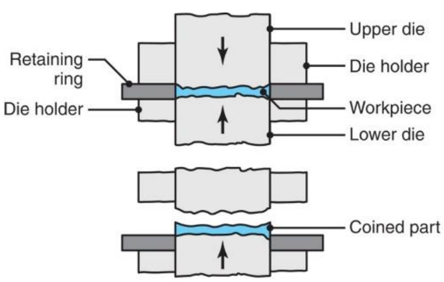


Figure 21: Coining

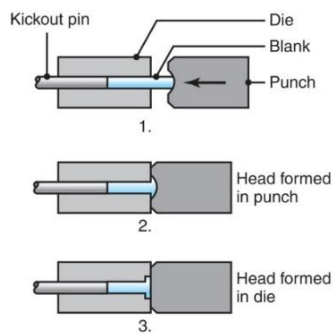


Figure 22: Heading

Exam Alert!

Extrusion

In **extrusion**, machines are definitely needed. It has **moderate-to-high die and equipment cost and low-to-moderate labor cost**.

The product geometry consists of long lengths, a *constant cross section* and it is cut for discrete products. Products made with extrusion are made in batches or semicontinuous.

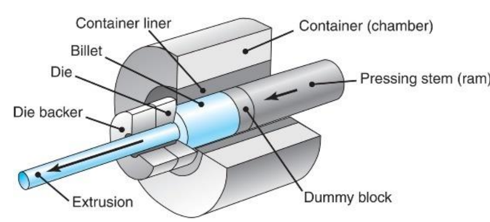


Figure 23: Process of extrusion

There are enormous forces for extrusion to make sure that the material is pushed through the shape. The die backer will make sure that the die will remain in place. The machine pushes the material to the die, and it will give a product.


Figure 24: Products made with extrusion

Cold extrusion

- High ductility.
- Combined with forging.
- $k = a * H_m$.
- For individual production

Hot extrusion

- Low ductility.
- Heat requirements.
- $k = C_{extr}(T)$.
- for batch production

Exam Alert!

Just like toothpaste, it is very difficult to get t erial out of the machine. But, if you are fast enough in adding more material, you can make 1 continuous product.

The higher the α, the higher the forces that are needed. The relief angle is at the place because the material heats up during forcing, and needs space to expand.

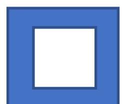
Very sharp corners, and unbalanced voids are hard to make with extrusion. Extrusion with very strong material is in practice not possible, since there will not be a die that can resist it. So, (EXAM QUESTION) it is **not possible to do extrusion with steel.** The forces would be to high for the die .

Example:

Exam Alert!

Starting material

- Length 10 m
- Diameter 17”



Required profile = outside 80mm, inside 50mm

Volume = 10 *(17*0,0354/2)^2* π = 1,46 m^3

1,46 m^3 = l * (0,08^2 – 0,05^2) (volume in=volume out)

So l = 374,36 meter.

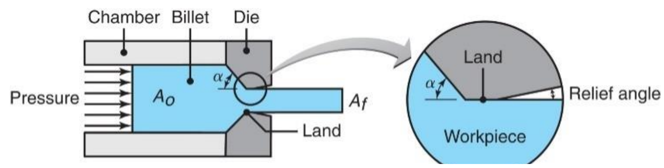


Figure 25: Detailed extrusion

Drawing

Drawing looks like extrusion. It has **low-to-moderate equipment and labor costs and low-to-moderate operator skills are required**. The product geometry consists of long rods and wires, and it can have different cross section. The process is **continuous**.

The big difference between drawing and extrusion is that in drawing the material will be pulled out of the die, and in extrusion the material will be pushed trough the die. There will be an optimum die angle. **Note that the drawing method will only work when the material is cold**! The material will become stronger since the method is a cold process.

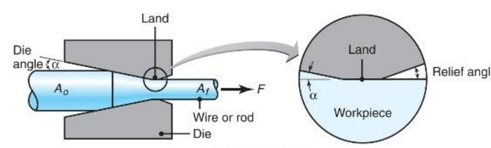


Figure 26: Drawing process

Sheet metal

Sheet metal components have extremely large surface-to-volume ratios. This implies that forces in sheet metal are foremost planar (2D). The thickness is usually 1mm - 1,5mm.

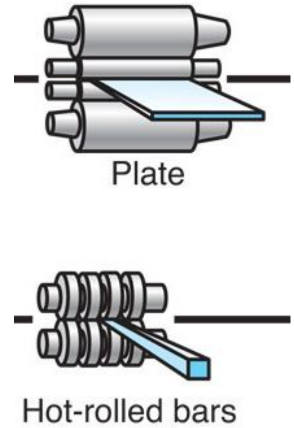


Figure 27: Metal Rolling

Metal rolling

Sheet metal is produced by metal rolling. Just role the metal until it is thin enough. It requires a lot of forces. In sheet and shape metal forming we have:

- Expensive equipment;
- Good surface finish;
- Low-to-moderate labor cost
- semi-continuous
- flat plates and foil, or profiles and rails.

Metal rolling can be hot or cold. When using hot rolling, the metal will be course-grained. A brittle structure of cast metal becomes a wrought structure with a finer grain. Course rolling will succeed in higher strength and hardness, and a better surface finish. What you very often do is to spray cold water on the hot metal before rolling it. That prevents a very hard surface layer of the hard metal.

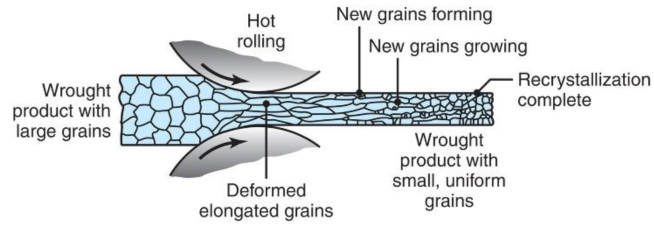


Figure 29: Hot rolling

Cold rolling will result in a higher strength and hardness, a better surface finish and of course anisotropic materials because the product is deformed in a cold way.

Making metal planes is not the only thing we can make with metal rolling, we can also make profiles.

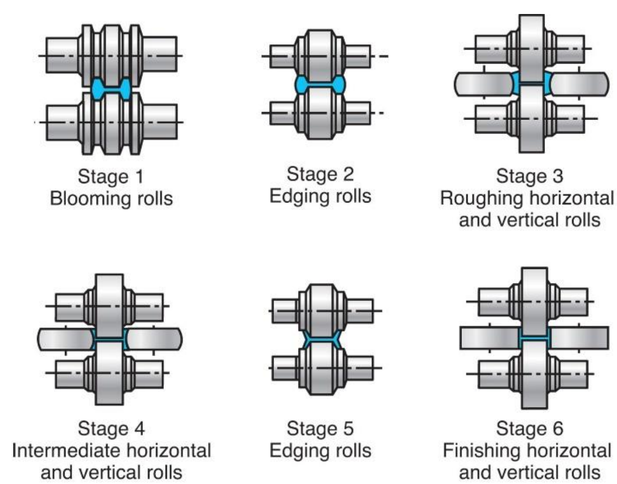


Figure 28: Profiles of metal rolling

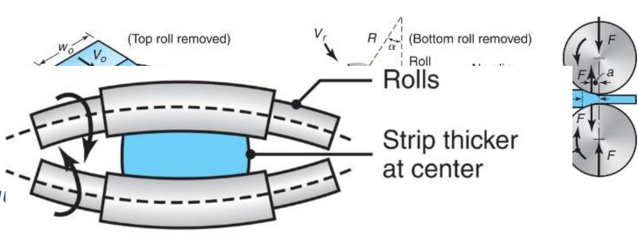
There are a few metal rolling specifics worth mentioning:

- Skew rolling (metal balls)
- Thread rolling (screw threats)
- Hollow tube rolling

Flat rolling

The fast majority of metal rolling is used for sheet metal. In other words, **flat rolling**. In flat rolling, friction forces the material through the gap. There is a relative sliding, due to constant surface speed of the role. Very often, we need a compromise on maximum friction and slip.

It is not possible to put endless thick materials through the rollers. Therefore, you end up very often by searching the thickets possible material. The bigger your friction can be, the bigger the material can be. The **maximum thickness of the material is**



Fig

determined by the friction of the roles. NOT the rolling diameter.

The compromise between fraction and slip are important because the forces are very high. The roles will always bend in the process due to the material. Therefore, the material will always be thicker in the middle then on the outsides.

It is possible to reduce the roll forces by:

Figure 31: Non-crowned rolls

- Using smaller diameter rolls. The smaller diameter, the smaller the forces, and the smaller the diameter, the smaller the thickness reduction.
- Smaller reductions.
- Back or front tension to the strip.

A way to reduce the bending of the material, we can used ***crowned rolls***. The rolls have to be a little bit thicker in the middle, so the material will become flat. There are also other methods to prevent a thicker center.

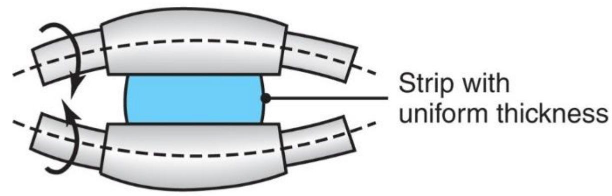


Figure 32: Crowned rolls

Sheet Metal Forming

Sheet metal is low costs to make, and it needs low skills. You can quite easily bend it without enormous forces. It is possible to make thin walls and a wide shape of variety. Sheet metal can be processed by bending, deep drawing, or explosive forming.

Processes of sheet metal forming

Bending

In bending, take a piece of sheet metal, put it between a lower and an upper die, and the die comes down and pushes the sheet metal into an angle. That angle is determined by the dies.

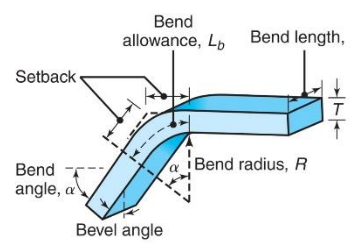


Figure 33: Bending Forces

Bending has to be very precise. There will be strain stress on the outside, because the metal will have to become longer, and compressive stress on the inside, because the metal will be crushed. The **bend allowance** means how far the metal is allowed to bend before it is going to crack. dependent on your rolling direction for cold steel, you will have a **minimum bend radius**. If you bend smaller than the band radius, your product will crack. The tow main methods are:

Free bending/Air bending

The die opening is wide. The punch comes down and the angle is determined by the punch. Calculations will be needed to get the needed shape. After releasing the punch, there will be a spring back due to elastic recovery of the plastically deformed sheet after unloading. Causes like distortion of parts and loss dimensional accuracy can be controlled by techniques such as overbending and bottoming of the punch. A **negative spring back does not occur** in air bending.

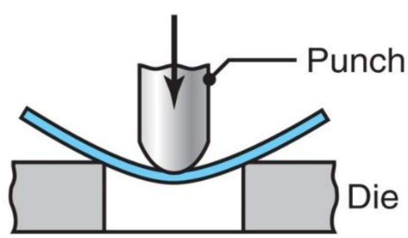


Figure 34: Free/Air bending

Closed Die bending

Two dies control the shape of the sheet metal. There will be no air in the system. We just put our punch to the lowest point possible. As soon as it is on the lowest position, you will release it and there will be a little bit spring back (possibly negative). The forces are high and it is really expensive.

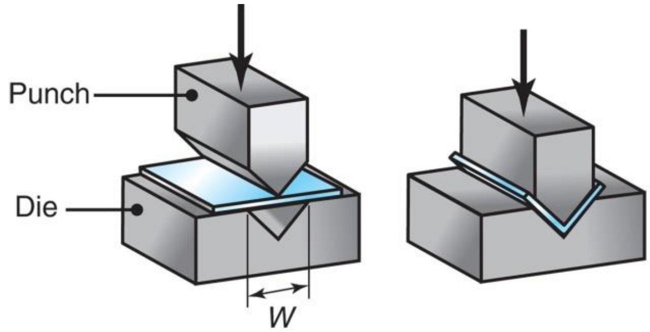


Figure 35: Die bending

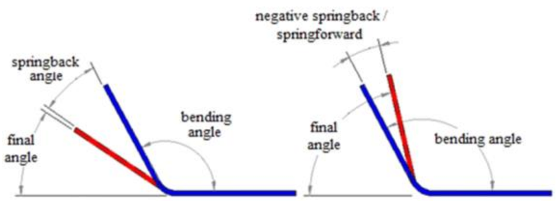


Figure 36: Spring back

Decreasing spring back

Decreasing the spring back can be done with a counterforce. It is just about giving a bottom to the punch. Predicting the spring back is still needed.

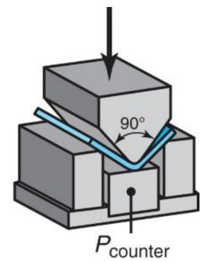


Figure 37: counterforce

Other bending methods

Roll bending

In roll bending, we have three roles with various curvature and a large radii.

Roll forming

Roll forming is a continuous rolling process with mass production.

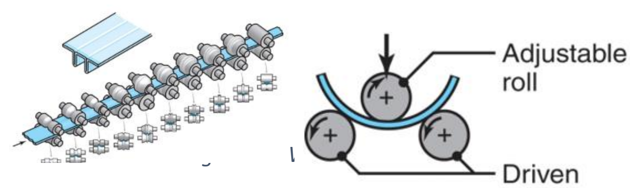


Figure 39: Roll forming and roll bending

Deep drawing

In bending methods, you will always have a straight line.
In deep drawing, you will make a product where the bottom and the walls are made out of the same piece. It is made with a punch and a die. In most of the times, you end up with a cup, rather then a sheet. Deep drawing is often done in different stages.

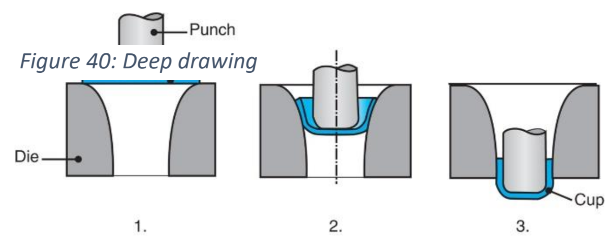


Figure 40: Deep drawing

If you find a product, made out of one piece**, the sides are thin and the bottom is relatively thick**, then you are almost sure that it is made with deep drawing.

Deep drawing is always a **cold forming process**. Because it is formed with cold materials, the material will have an anisotropic behaviour. The wrinkling in deep drawing is reduced by a blank holder.

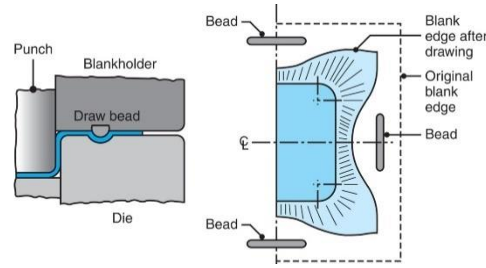


Figure 41: Preventing wrinkling

Explosive forming

Explosive material generates pressure. We put an explosive in water, it causes a huge shockwave in the water, the forces put the metal into the right pace.

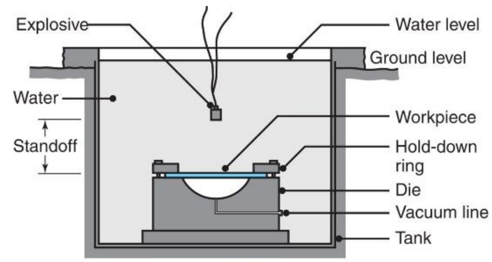


Figure 42: Explosive forming

Forging machines

In forging, we need several hammers, think of drop hammers, counterblow hammers, or hydraulic hammers.

Also presses are needed. Think of mechanical presses, screw presses, or hydraulic presses. When choosing the machines, you have to take into account the press force, press speed, accuracy, speed, contact time, and stiffness.

Separating

Mechanical

Separating = removing material without changing its structure. We want to avoid heating up the material and changing the crystalline structure. We simply want to cut away the material without damaging the material itself. The goal of separating is to lose as little material as possible. We want to avoid making chips or sawdust as little as possible. We do not want to lose any material in the process.

*Mechanical separating – **without chip -forming***

There are several mechanical separating techniques without chip-forming.

- Cutting (like a knife).
- Punching.
- Nibbling.

*Mechanical separating – **with chip -forming***

There are several mechanical separating techniques with chip-forming. We only allow a little bit of chip forming.

- Sawing (you will generate a little bit of sawdust)
- Grinding, friction sawing
- Milling

Physical separating

Physical separating uses focused energy to separate materials. It comes in the following forms:

- Flame-cutting, plasma-cutting, laser-cutting.
- Wire electro discharge machining (wire-EDM).
- Waterjet-cutting.

Terminology

Punching: Removing the inner part

Blanking: Removing the outer part

Perforating: making holes on the inside of the product.

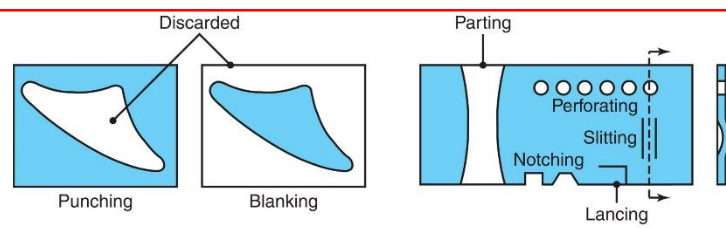


Figure 43: Punching, blanking, perforating, etc.

Notching: Make notches(holes on the outside)

Lancing: The material is sliced or cut without producing a slug or separating the workpiece.

Slitting: Making an indentation in the product.

Mechanical separating

The main principle of mechanical separating is always the same. A punch comes down, and will take away a part of the sheet. During the mechanical separating, there is not enough room to allow for the sheet to deform. All products that are produced with **mechanical separating**, will confront you with **sharp edges and rough materials**.

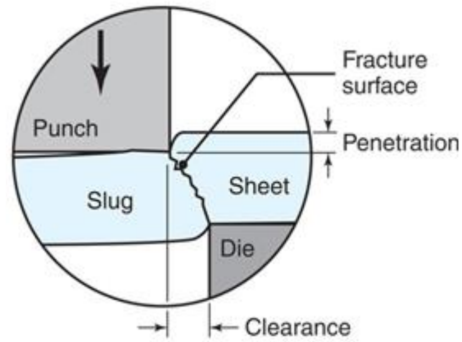


Figure 44: Mechanical separating

Parting

We have a universal tool with a bottom blade and a die. The metal sheet is clamped by the clamp. That will prevent tilting. The moving blade of the parting machine comes down, and cuts away the material.

The moving blade cuts away the material under a **shear angle**, to reduce the forces. The shear angle is on average 12 degrees. The angle will depends on the thickness of the sheet metal. This will require a lot less forces then a horizontal moving blade.

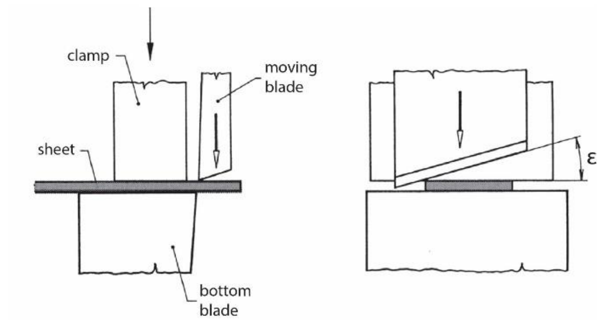


Figure 45: Parting

Slitting

In slitting, we again have a die and a punch. But in this case, rotating cutters are used. One of them is driven, the other one just follows. By using the slitters, you can follow a **specific geometry** which will give a specific separation line.

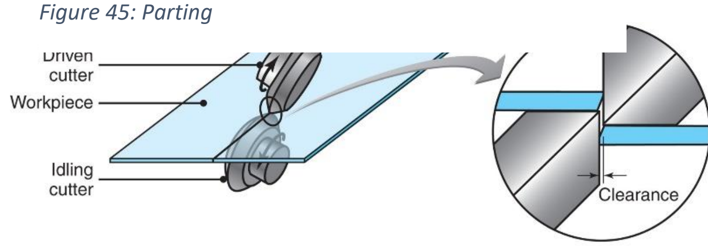


Figure 46: Slitting

Punching

For the process of punching, we can think of perforating **paper with a perforator**. In this case, we use a shear force, and we push down a punch making a hole in the product. The shape of the hole is determined by the shape of the tool. Therefore, we say that the tool is the information carrier.

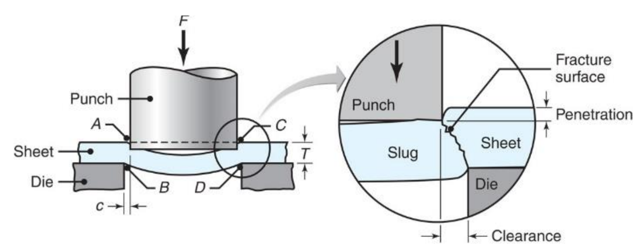


Figure 47: Punching

Forces in punching

The process of punching happens in tenths of seconds. Therefore, we will need enormous forces. Punching is a quite linear process for several characteristics:

- Sheet thickness. (e.g. if you double the sheet thickness, you have to double the forces)
- Shear strength.
- **Perimeter** of the tool geometry. (e.g. if the perimeter of the tool doubles, the force doubles).

punching force = (sheet thickness) x (shear strength of material) x (perimeter of the tool). Reducing the punch force could be done by adding a **shear angle**.

Rule of thumb: Never make holes that **are smaller or even close to the sheet thickness**. It would be impossible to make, because the forces are too high and there is a high probability that your punch would break.

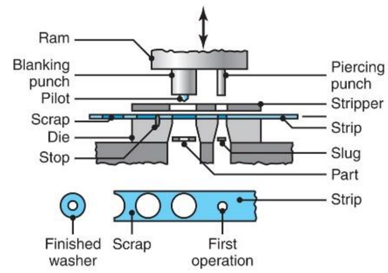


Figure 48: Progressive die

Progressive die

Many times we do not need only one hole, but a combination of punching and forming. In that case, we will use a progressive die. A progressive die is a **complex die with multiple punches** which will all make holes at a different place. A progressive die allows us to just feed one strip of material, and finish the product in 1 go.

Nibbling: using multiple steps to reach the final shape we want (approximating the shapes we want). Think of using multiple punches to reach the needed shape.

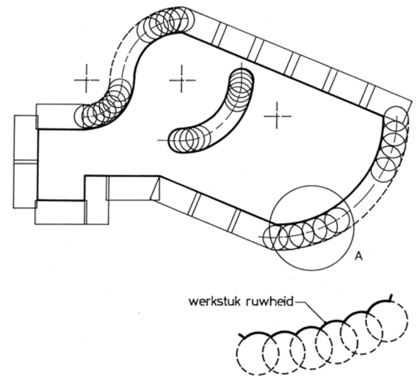


Figure 49: Nibbling, approximation of a shape by different shapes

Exercise, determining if specific tools are financially justified

Imagine that you are a producer of key-holes. You can either use generic tools, or a special tool.

Assume that the machine costs are € 160.00 /h. Each tool stroke takes 2 seconds (positioning + punching). The special tool costs € 250,00. The generic tools cost € 20,00 each. For the generic tools, a tool change takes 2 seconds.

What is the production quantity that justifies buying a special tool?

$$\frac{€\,250,-}{NP} + \frac{2\,sec}{3600\,sec} * €\,160,- = \frac{2 * €\,20,-}{NP} + \frac{2 * 2\,\text{sec} + 2\,sec}{3600\,sec} * €\,160,- \quad \Rightarrow \quad NP = 1.182$$

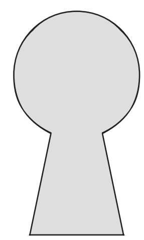


Figure 51: Specific tool

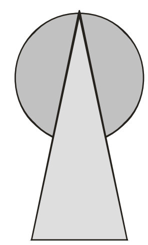
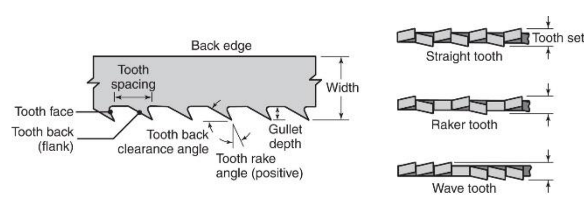


Figure 50: Generic tool

Sawing

Sawing is a mechanical process with chip-forming, since it takes away a little bit of chips. The saw is just a straight line, so the geometry you will get will be determined by how you move the saw, rather than the saw itself. The information on geometry are not in the tool.

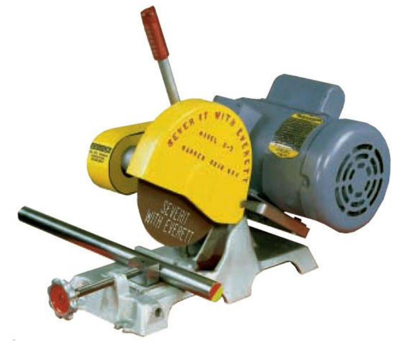


A decent saw will have the tooths not in a straight line. That prevents clamping. The tooths that are not in a straight line, will give some clearance to the rest of the saw.

A circular saw will rotate with a number of revolutions per minute. That determines how many teeth will touch your material per minute. Obviously the higher the revolution speed, the higher the cutting speed will be. But also, **the bigger the radio, the higher the cutting speed**.

Grinding

A grinding process looks a lot like the sawing process. It only has very, very, very small teeth. The principle is the same. The **friction forces are much higher**. In grinding, we need a proper surface finish, but the temperature should not rise too much. Therefore we need to cool the machine. There are two ways:



- **Wet (up to 50m/s).** it is very hard to get liquid where you want it if it has a higher speed then 50m/s. It will easily swing away the material.
- **Dry (up to 100m/s).**

Physical separating

Physical separating mainly uses flame-cutting, plasma-cutting, laser-cutting, wire electro discharge machining, or waterjet-cutting it is about high energy separating. The energy will separate our product rather than we need a tool. Uses **(almost) no forces.**

It is a non-mechanical process .We look at working that are independent of mechanical properties. All these physical processes are concentrated on **energy to separate** the products. It is very specific energy focused on only one spot. This means:

- **Possibility of a narrow cut.**
- **Heat effected zone.**

Flame cutting

Flame cutting sets fire to the material (**burning it away**) rather then melting it. The source of energy is a burning mix of gasses which is used to separate the components. The burning temperature for metal is lower then the melting temperature. There are several characteristics of flame cutting:

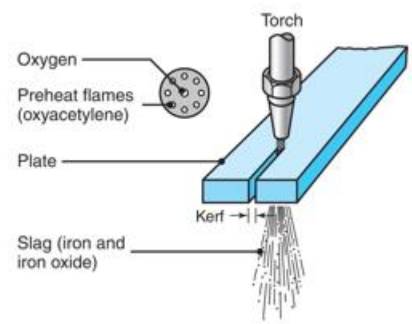


Figure 52: Flame cutting

- Rapid burning of the material. The processes creates damages like the grading slug.
- Contour cutting is fairly easy.
- Multi-layer cutting is possible.
- **Cutting very thick** materials is possible.
- Cutting very thin sheets is not preferred. The material will burn and melt away and the holes/contour we are cutting will be less predictable.
- The burned surface will not be shiny. In other words, the **surface roughness is very high**.
- The big **advantage** of flame cutting is that you can bring the tools for cutting wherever you want, there is not special machinery needed.
- The disadvantage of flame cutting is that it is not a subtle process.

Plasma cutting

Plasma cutting has a bit a higher quality. We actually we add a tungsten electrode in a wolfram. That will cause a voltage difference **between electrodes and the workpiece** which will create ionization of gas. That means that the gas will burn even more fiercely, and in that way we can reach extremely high temperature up to 30.000 *C. It has several characteristics:

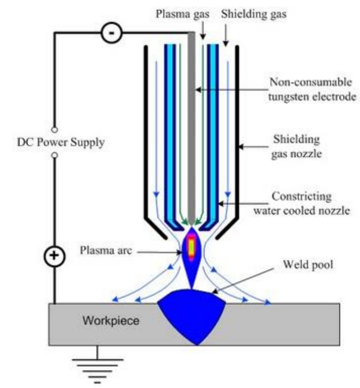


Figure 53: Plasma cutting

- Plasma cutting uses **extreme temperatures**.
- We can cut faster and concentrate the energy better where we want.
- Plasma cutting is **more precise** then flame cutting
- Plasma cutting has a **better surface finish** then flame cutting.

However, with plasma cutting we need a **bigger power supply and a bigger machine**!

Laser cutting

In laser Cutting (Light Amplification by Stimulated Emission of Radiation) we use light that has the same frequency (wavelength) in a very concentrated way. In that way, we reach extremely high temperatures (e.g. 10.000 degrees) and cut away the material. We can do it in several ways. Laser cutting has several important characteristics:

- We can cut steel up to 30mm, beyond than it is difficult.
- We can cut with the **use of oxygen**. In that way, the steel will oxidate and therefore we can **burn harder and thicker layers** of material. This process will decrease the quality and introduce rust.
- We can cut with **inert gas** (gas that doesn't contain oxygen and pushes the oxygen away). That will create a **very clear cut** without damages.
- We can reach **very narrow cuts** with a small heat affected zone.
- It has even more precise finish than flame cutting and plasma cutting.
- Cutting **sharp corners** is hard. If we use a regular laser beam, we will burn the material. We will need a **pulsed beam** (which is not continuous) which does not overheat the material.
- The laser source is outside the machine. We don't move heavy machinery, we use flying optics (mirrors). Those mirrors reflect the light to the point where it is actually needed.
- In fact, the laser has an "X – shape" which can be seen in the drawing. The dot is the point where the lasers come together, which will have the highest energy density. We want that density at 1/3 at the height of our sheet.
- Whatever you do in laser cutting, any cut part will have a **typical X shape** that will not be cut away.

- Limitation of laser cutting: below the focus point of the non-parallel beam, the energy density will decrease. At some point the laser light will be so wide that it won't cut anymore.

The process is hampered by reflection and conduction. It is possible to create a narrow cut. There is only a small heat affected zone.

Laser machineries always use mirrors, because the machines that produces a laser are to heavy to move. There is a lens, that increases the diameter to reduce the density of the light, otherwise the mirror would burn away.

Next to laser cutting, we can also do:

- **Laser drilling**
- **Laser engraving**
- **Laser welding**
- **Laser soldering**
- **Laser bending**

There is one main problem in laser cutting, a lot of the used light will be reflected by the material. All that light cannot be used for the process. The **amount of reflection has to do with the material and the wavelength** of the light.

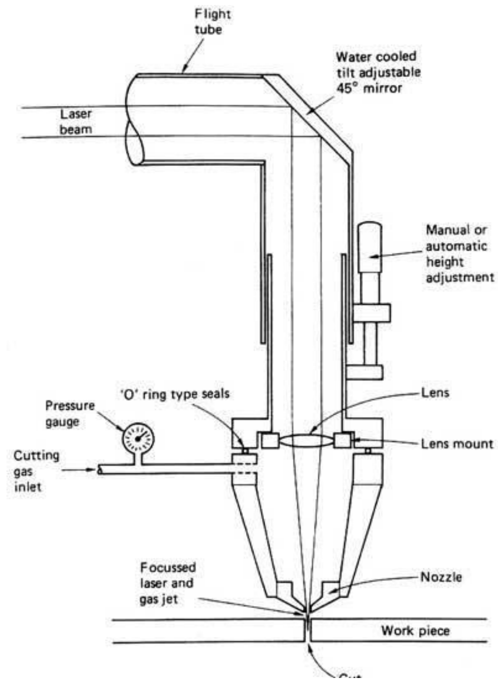


Figure 54: laser cutting

Wire-EDM -> separating, normal EDM is 'other processes'

In wire-EDM, a wire comes close to the workpiece but will not touch it. We use quite a high current in there which means there is a **high voltage difference** between the wire and the workpiece itself. If the wire comes closer, In a certain point of time the room which is filled with a liquid cannot withstand the current anymore. The **liquid is a "dielectric**", a liquid that withstands a voltage difference

The advantage is that we take away very tiny parts of material, the disadvantage is that it is **very slow. It can be very precise.**

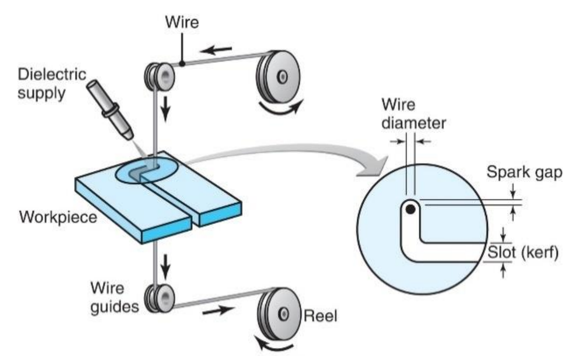


Figure 55: Wire-EDM

The geometry is defined by how we move the wire. It has an **accurate and smooth surface finish** and it is a subtle process.

The electrode itself is a wire with a diameter of 0.05 to 0.5 mm. The wire gets damaged by every flashed, thus the machine adds new wire continuously. Thousands of flashes happen per second.

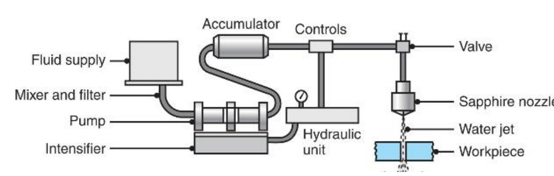


Figure 56: waterjet cutting

Waterjet cutting

Waterjet cutting uses a small stream of water under **enormous pressure (400 Mpa**). It easily cuts away material. The radius (<1 mm) comes out of a jet and you can take away paper, textile, plastics.

If you want to cut **metal, you have to add abrasive material** (particles). These particles can be sand or other things. Then it will cut trough very hard material. **Oxidation** can happen because we are using water, oxygen and metal. Waterjet cutting is not a very subtle process.

Machining

General

Machining is the **removal of the material or modification of surfaces** without changing the structure of the material. It is done

- Without changing the structure of the material since it **does not heat up**.
- By **producing chips** for removing material using various tools.

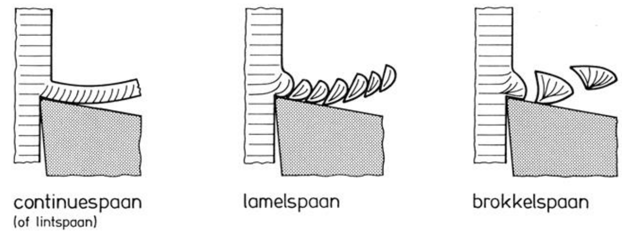


Figure 57: Different types of chips

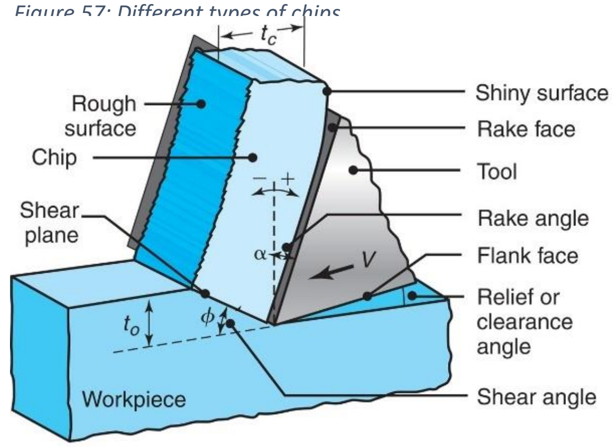


Figure 58: Machining with rake, tool, and relief angle

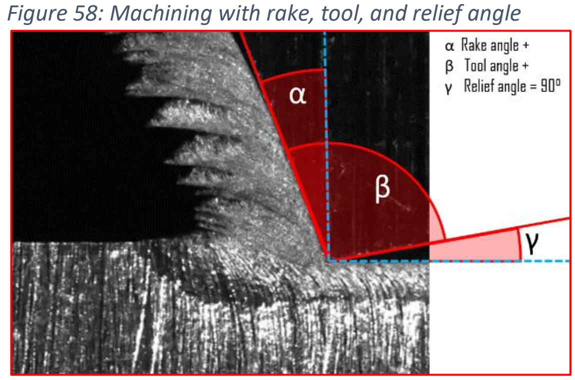


Figure 59: Different cutting angles

Note that **chip control** is very important in machining. A big bowl of chips can damage what you are doing. Machining has several characteristics:

- Machining allows us to make **complex shapes**.
- The tool does not have information about the product geometry.
- Machining has **good surface finish**.
- Machining has **good dimensional accuracy**. It depends on the knowledge of the operator which translates from the tool to the material.
- **Generic tools** are used, not special machines so we do not have to order special machines or dies.

Different Angles in Cutting

In machining, there are different angles that are worth mentioning.

Rake angle = Angle of the cutting tool relative to the work. It is mentioned with α (in figure 64 it is negative).

Relief / clearance angle = Angle between the horizontal surface and the cutting tool. It is mentioned with γ.

Tool angle = the angle of the tip of the tool, which is β

Shearing angle = The angle made by the shear plane with the direction of tool travel (see figure 63). It is mentioned with ϕ

Important: Rake angle (α) + Tool angle (β) + Relief angle (γ) = 90^{o}

The bigger the rake angle (the flatter the tool lies), the lower the forces need to be to cut away the material. In all tools that you are making, try to **make the tool angle as big as possible** because the bigger the tool angle, the **stronger the tool tip** will be. Because of that, the tool will last longer.

The relief angle is needed because the workpiece locally heats up where the tool makes contact. Its volume will expand, and therefore it needs space.

Machining processes

The name of the machining process depends on the type of machining:

- If the **workpiece rotates**, it is called turning, cutting off, or hole making.
- If the **workpiece slides**, it is called scraping.
- If the **tool rotates**, It is called slab milling or end milling. If the **tool slides**, it is called scraping or broaching

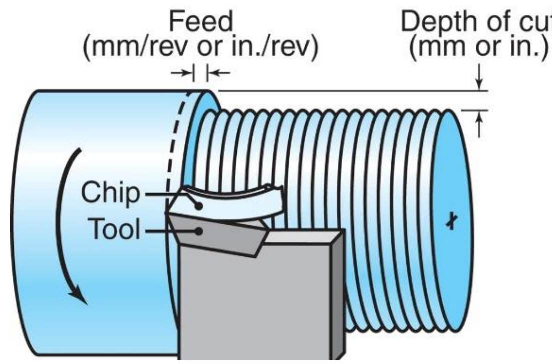


Figure 60: Process of cutting

Operating factors

Machining is a simple process. There are different operating factors that occur during machining processes. For the cutting those are:

- Depth: Pushing the tool into the workpiece.
- Speed: The rotation of the workpiece, number of revolutions per minute.
- Feed: The amount of time it takes to cut away the material by moving the tool along the length of the workpiece (measured in movements of the tool per rotation of the workpiece).
- Tool angle: Adjusting the tool angle can change the forces.
- Type of chips.
- Tool wear: One of the **bigger problems** in machining.

Fluids

Fluids can be used for cooling or changing the forces a bit, reduce friction and wear, flush chips away, or protect the machine from corrosion. There are different types:

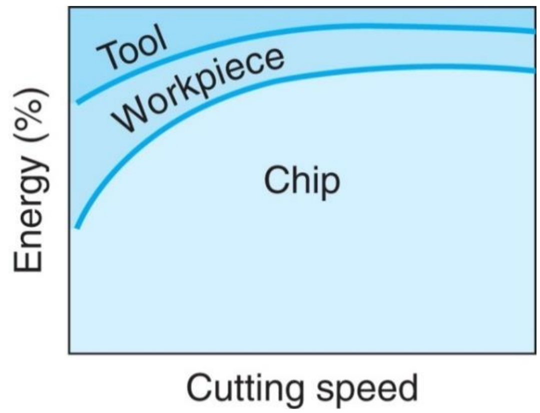
- Oils: For **low temperatures and low working speed**, oils can be used. High speed will result in a big risk of burning the oil.
- Emulsions: Used for **high speed and high temperatures**. This is a mix of water and oil
- Semi-synthetics: Most of the time **little oil in water**.

- Synthetics: **Chemicals and additives in water**.

Temperature

The workpiece is relatively cool because **most heat is removed by the chip**.

Because of the temperature, there can be wear on both sides of the tool. At a moment in time, the wear will be too much, so the tool will break and your product geometry will differ from your original idea.



Cutting forces

The cutting force depends on:

- Work piece **material**: The stronger the material, the higher the cutting forces.
- **Rake angle**: The bigger the rake angle (the flatter the tool) the lower the forces.
- **Feed**: The lower the feed, the lower the cutting forces (**potentially higher quality surface** finish)
- **Depth**: The lower the depth, the lower the cutting forces (**potentially higher quality surface** finish),

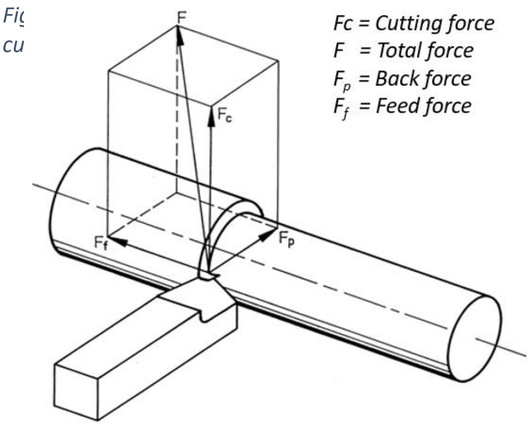


Figure 62: Cutting forces

Tool Characteristic

The wear stresses how important the tool characteristics are. Therefore, the following characteristics are very important:

- **Hot hardness**. Even if the temperature rises a lot, it will be hard.
- Toughness and impact strength
- Thermal shock resistance
- Wear resistance
- Chemical stability and inertness.
- Iso classification.

Also note that different tools have different cutting speeds. The materials in order of speed are: **Tool steel, High speed steels, Hard metal, Coated Carbides, Ceramics, Cubic Boron Nitride, Diamond**.

Tool life

Different materials have different tool cutting speed. The life of a tool can be measured with the tool-life equation:

$$\boxed{V_c * T^N = C}$$

Ranges of n Values for the Taylor Equation (21.25) for Various Tool Materials	
High-speed steels	0.08–0.2
Cast alloys	0.1–0.15
Carbides	0.2–0.5
Coated carbides	0.4–0.6
Ceramics	0.5–0.7

In this case the cutting speed (V_c) $*$ the tool life (T^N)to the power of N (dependent on the tool material) will be a constant. Dependent on the tool characteristics, the life time of the tool will be changed:

- The constant (C) increases with decreasing depth of cut.
- The constant (C) increases with a decrease in feed.
- The constant (C) is affected by all factors around the machine

Figure 64: Values of N

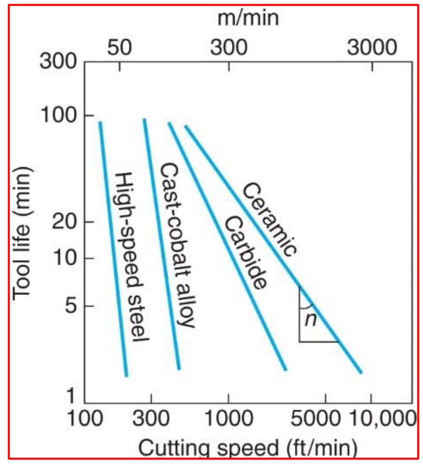


Figure 63: Tool life for different materials

Example

A lathe (turning machine) manufactures 12 products per hour. The tool has the following characteristics:

- Hard metal: n = 0.2
- Tool life: T = 15 minutes
- Speed: V_c= 5,0 m/s
- 5 minutes per change

A manager comes in and wants to increase production by increasing the cutting speed to V_c = 5,4 m/s. What is the new amount of products that are produced every hour? (rounding off is allowed)

Answer:

EXAM ALERT

Cutting length: 5,0 [m/s] x 60 [sec] x (3 [tools] x 15 [minutes]) = 13.500 m
For 12 products: = 1,125 m/product
Using Taylor:
$5{,}0 \times 15^{0{,}2} = C = 5{,}4 \times T^{0{,}2}$ T = 10 minutes
Cutting length: 5,4 [m/s] x 60 [sec] x (4 [tools] x 10 [minutes]) = 12,960 m
New situation: 12,960/1,125 = 11.52 products/hour

So, a higher production speed does not necessarily mean a higher production rate.

When we look at the cutting speed/costs per piece graph, we can't find a break-even point (point where curves cross) and say it is optimal. We can only add up the costs to meet the **minimum point of the condition**, which will give us the optimum.

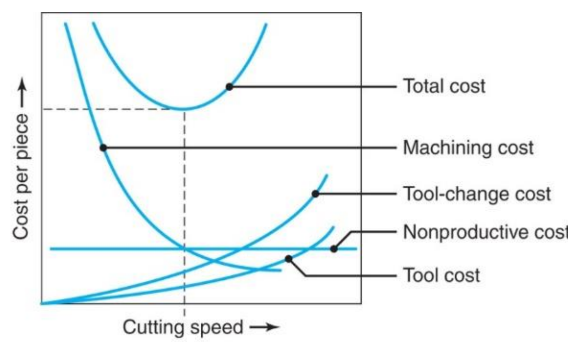
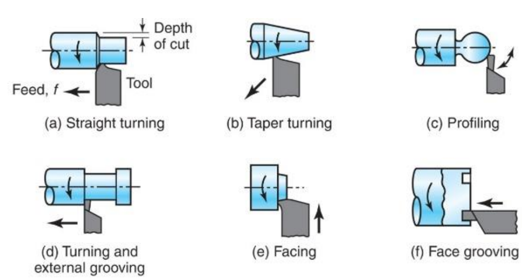


Figure 65: tapping

Turning

Turning indicates that the **workpiece will be rotating**, and the tool will be stationary. In turning, the product will be rotationally symmetrical. It has several characteristics:

- Product geometry: **Rotational symmetrical**.
- Product materials: All kinds of materials.
- Advantage: Use of **generic tools**.
- Disadvantage: The tool has to move along the whole geometry of the product. It has a **low production rate**.



- Operations: The cutting speed in the middle of the diameter is 0, **thus tools will not cut the inner part, the material just chips away**.

Figure 66: Turning tools 1/2

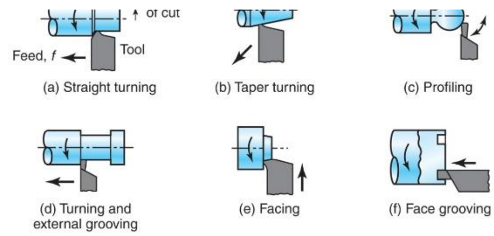


Figure 67: Turning tools 2/2

For turning alone, there are many tools possible, as can be seen in the figures. Note that the production of different tools can be very expensive .

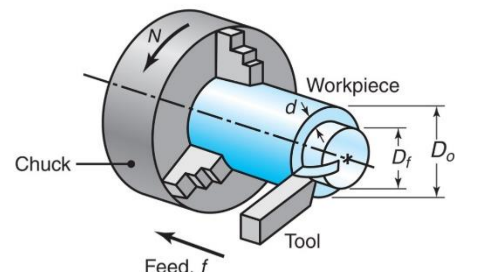
Facing = working on the front size of a rotating product.

Straight turning = make the diameter of the product smaller

Parameters

There are several parameters to take into account:

- D = cutting depth
- F = feed
- N = rotation



The cutting speed of a turning machine can be determined as follows:

$$\boxed{Cutting\ speed = \pi * D * n}$$

The tool itself is very expensive, therefore a toolholder is used of a different material to get the tool in place.

Figur

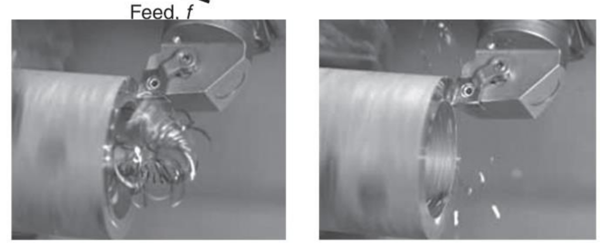


Figure 69: Chip breaker

Chip control

Sometimes, the chips that are made with turning will not brake and become to big. The tool might get damaged by those chips. Therefore, chip breakers will be used in a continuous process.

Surface finish

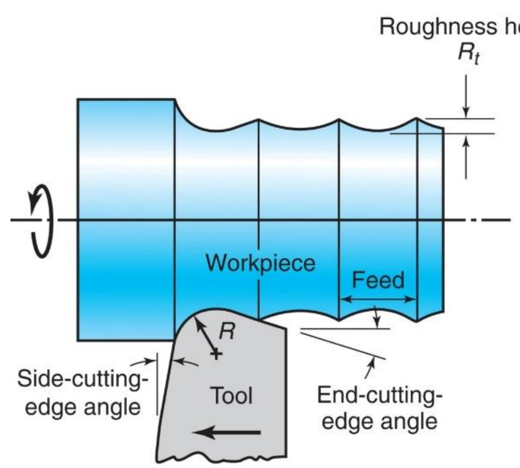


Figure 70: Surface roughness

There are aspects of turning that will create surface roughness. Dependent on the tool geometry, and the speed in which we move the tool, the surface finish will be different. Making your tool sharper will increase the surface quality. The type of surface roughness can be found in figure 75. Explicit factors in the **surface finish are:**

- **Feed rate (f)**
- **Tool geometry (r)**

Tools

As said, the insert has to be as small as possible. There are many different shapes of inserts. The rule is, the **rounder a tool, the stronger** it will be.

However, **sharp tools will give a better surface finish**.

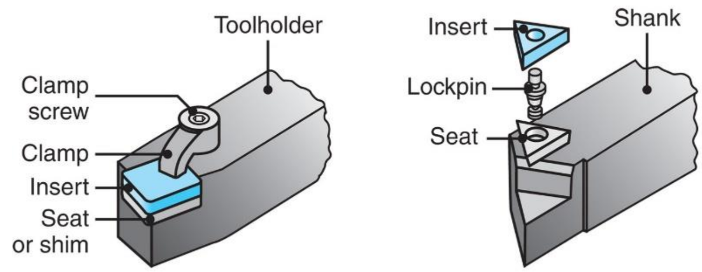


Figure 71: Tool holder

The used tool is called a “Guided lathe”, which is a very big machine. It is also possible to put it on computer-numerical control. It prevents the use of a very big tool, which is expensive.

Requirements

The size of the product matters, if you do not have a machine that is big enough to manufacture it, you cannot make it. So, the **size, shape, position and surface tolerances** are important .

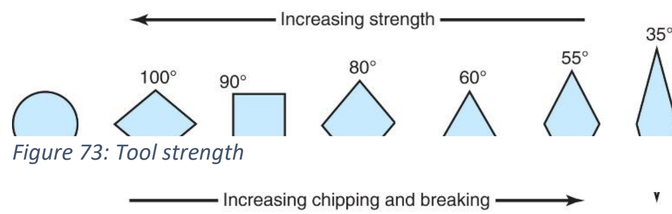


Figure 73: Tool strength

For the tool requirements, the maximal speed is important. Also minimizing the costs is important. The machine should also be able to provide us with the number of revolutions that we need.

Product geometry

Copy turning = measure the lines of a template (or the previous product) to make the new product.

Several products that can be made with turning are **housing bases, inner bearing races, rube reducers, or screw threads**.

A lot of simulations are used for two reasons:

- The logistics sense, can we speed it up?
- Will our tool be able to reach every part. Can we make what we want to make?

<u>NOTE: Turned products are always rotational symmetrical!</u>

Boring

Boring means **making a hole larger** with as little force as possible. Boring uses large machines, the whole table rotates and the big machine pushes material away. Boring can be viewed as the internal-diameter counterpart to turning, which cuts external diameters.

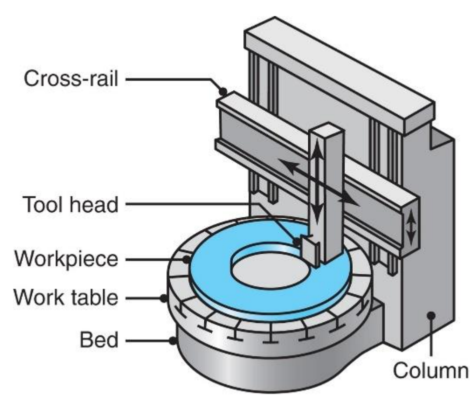


Figure 74: Boring

Drilling

Drilling is the process of **cutting holes** in a solid material using a rotating cutting tool.

- Tool geometry: It will immediately determine the shape of the hole. The **maximum hole depth is related to the diameter** of the tool. That is because of the forces that are on the drill when drilling.

- Feed force: Pushed against the material.
- Torque: The **rotational force** between the drill string and the formation.
- Tool wear: Determined by the **remaining useful length** of the drill after sharpening. Sharpening is not always possible.
- Rake angle: The rake angle is used to reduce the forces, and makes it easier to drill .Rake angles vary from the diameter:
    - **Positive (outside).**
    - **Negative (inside).**

Note: It is important to **clamp the material** before drilling, otherwise it would be flying around with the speed of the drill.

Reamers are designed to **enlarge the size** of a previously formed hole by a small amount but with a **high degree of accuracy to leave smooth sides**.

It is possible to make **screw threads** in a hole. That is done with **tapping**. If we screw the tap, it will make the right screw tread.

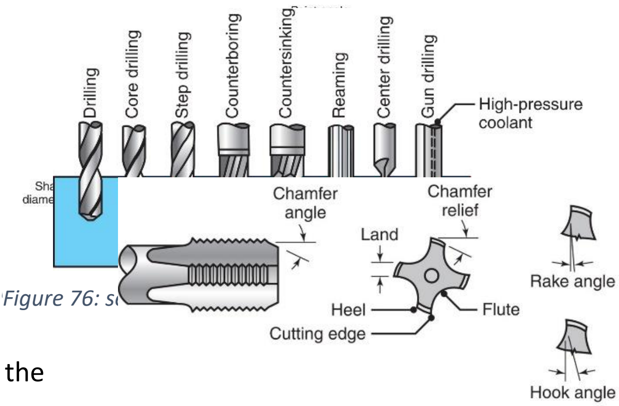


Fig Figure 76: s

For drilling through thin material, **flow drilling** is used. It is actually not drilling but more **melting through** the material .

Grinding

In grinding processes, we have a moving tool. A grinding disc looks from a distance almost like a cylinder. If you come closer, you will see that it actually consists of a lot of grains. These grains are all unpredicted shapes. Each grain will scrape a little bit of material away.

Since we only take away very little pieces of material for each grain, the **removal speed in grinding will not be very high**. A typical application for grinding is to **increase the surface quality** of the product and for **removing thin layers**.

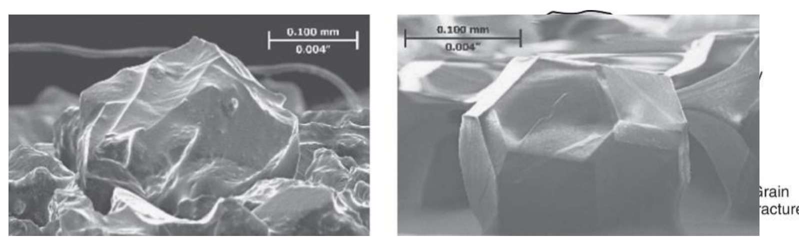


Figure 77: Grinding disc & grains

Grinding has several characteristics

- A disc with a large number of undefined cutting edges.
- Grains **exposed to very high forces** Because they have a strong negative chip angle.
- The specific cutting force is much higher then milling.
- Small machined volume per minute.

Grinding looks a lot like milling. But, the direction is less important. Note that in grinding, there is only a minimal contact point between the grinding disc and the workpiece.

Characteristics of the tool

Exam Alert!

The grinding disc has a lot of abrasive grains. Those grains can be made of different materials (think of industrial diamond, aluminium oxide). Those grains take away the chips. The **size of the grain influences**

the surface quality and the removal speed. Of course, bigger grains will increase the removal speed, but decrease the surface quality.

The structure of the disk is also important. Between the grains, there is some space and that pore size has to do with if we actually can saw the chips, and if we can get rid of the heat.

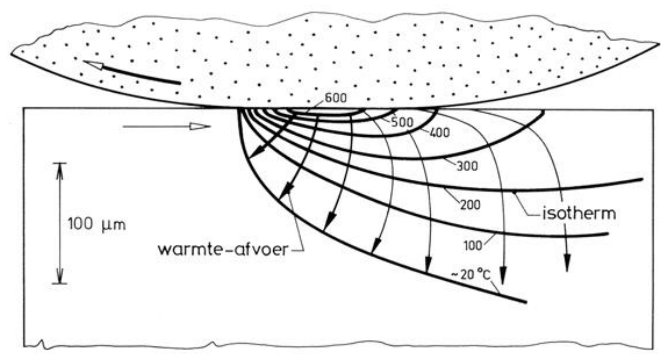
The grains are bound together, by a so called binding agent or with a kind of glue. That can be done with ceramic binding, silicate binding, elastic binding or metal binding. We use different kind of glues to bind together the grains. The hardness of a grinding disc is not determined by the hardness of the individual grains. The grains can be extremely hard, but if the glue is not very hard, that will also determine the harness of the disc.

<u>Hardness of the disc is determined by the strength of the binding between the grains, not by the strength of the grains itself.</u>

If grains break away from the disc, your disc will lose volume. That is something that you have to take into account.

Grinding temperature

Because of the high forces, there will be an increasing temperature. The **heat drain is for 70% in the workpiece**. After removing material it will decrease again. Note that there can be some problems. Because of the high temperature several things can happen:



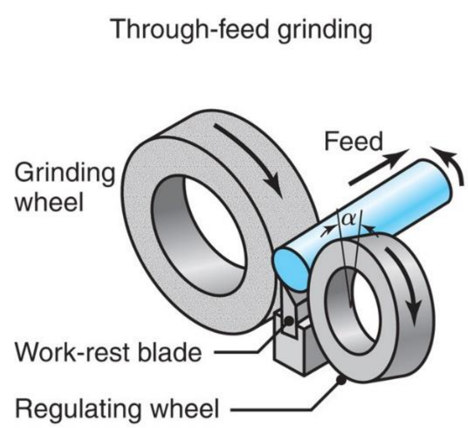
- **Change of material structure.**
- **Surface cracks.**
- **Geometric inaccuracies**.

Therefore, sometimes cooling systems are used. A **water-oil emulsion could be very accurate**. Also note, at a high revolution speed, grinding disks cannot be cooled effectively. The cooling fluids can hardly reach the disk because of the centrifugal forces.

Centerless grinding

In centreless grinding we have a grinding wheel, and a regulating wheel, and we make sure that the machine can determine the distance between those two wheels. The workpiece is clamped between the two wheels.

Also, note that the amount of products that are needed will determine the method.



Milling

Milling is the process of machining using **rotary cutters to remove material by advancing a cutter into a workpiece**. The tooths of the milling tool will go through the material, and each will chip away a little bit of material. Milling tools have several characteristics:

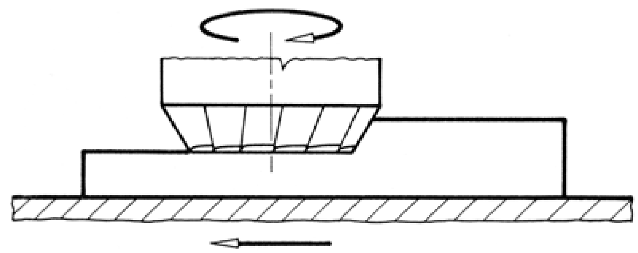


Figure 78: Milling

- It moves with respect to the workpiece.
- It is a rotating tool.
- The teeth are perpendicular to the axis of rotation.
- The tool is like a flex, flat to the surface of the material.

It is typical for milling to have **shorter chips** because the teeth are not continuously touching the workpiece. While milling, the miller leaves away a **wavy pattern**. That is a **bad surface quality.**

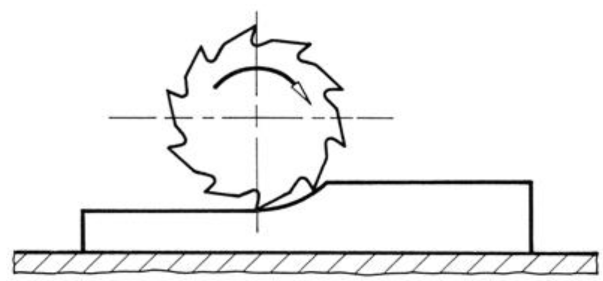


Figure 79: Milling

Milling strategies

In milling, there are several different strategies that can be used.

Climb milling

Climb milling (down milling) has several characteristics:

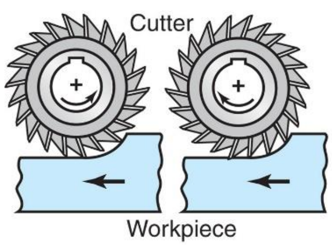


Figure 80: conventional & climb milling

- The cutter rotates along the direction of the table feed.
- Chip load on teeth decreases gradually from maximum to zero.
- Cutting force is directed downward, and thus it tends to press the workpiece rather than lifting it off.
- **Burr** is formed at finished surface in opposite side of the tool feed.
- **Surface quality will be higher**.
- Drawback: **Instant forces are very high**.

Conventional milling

Conventional milling (up milling) has several characteristics:

- The milling cutter has the opposite direction of the workpiece.
- The forces are **slowly increasing** which is better for **very hard surface materials**.
- **Surface quality lower** than for climb milling.

A characteristic of milling is the **changing chip thickness** and **changing temperature of the tool**.

Milling machines

Many times, we need a specific geometric characteristic with milling, therefore different types of milling can be used.

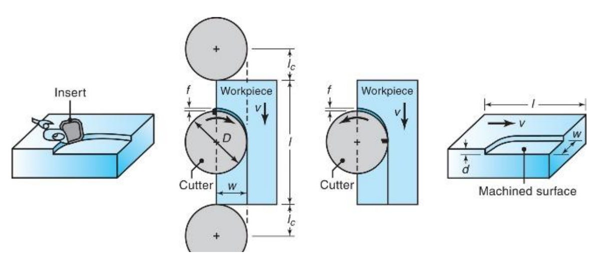
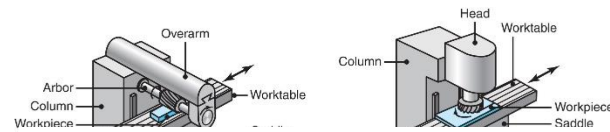


Figure 81: Face milling

There are two interesting types of milling. **Peck milling** and **end milling**. The only difference is that peck milling is able to drill, and end milling is not able to drill.

Usually, there are two different types of milling machines. **Horizontal and vertical.**



There is also one process where the tools only move in a linear direction. Then it is called **broaching**. It is more or less a linear mill (does not turn, is not round) where each of the teeth extends a bit more than the previous one.

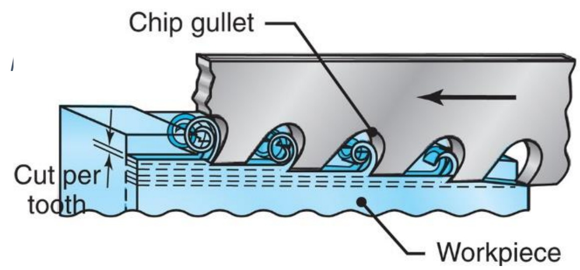


Figure 83: Broaching

Other Processes

Many machining processes are based on the principle that there is a sharp tool cutting away some material, but there are other processes needed for special products.

Electrical-discharge machining (EDM)

In EDM, we provide a current and with that current we create wat is called an electrical discharge like a flash of lightning, and that discharge will melt or evaporate extremely small particles. We don't make big chips, but we are talking about really tiny chips. We immediately **turn the solid metal into a kind of gas**.

For this purpose we use electrodes with 100-300 volt. It also has an amperage of 5-200. The hole process is done under an **dielectric fluid**. The fluid tries to separate the electrode from our workpiece.

If we need to remove a lot material, we use a pulse generator which can produce a lot of discharges. That has a power of 50 – 1000 KHz. The small parts that are removed are actually a metal, so if it will stay in the fluid, the fluid will become conductive. Therefore, we need a **rising system** that takes away the access material.

We have to be very careful, because it is a very precise process. Therefore, we need a gap width control system.

There are several applications:

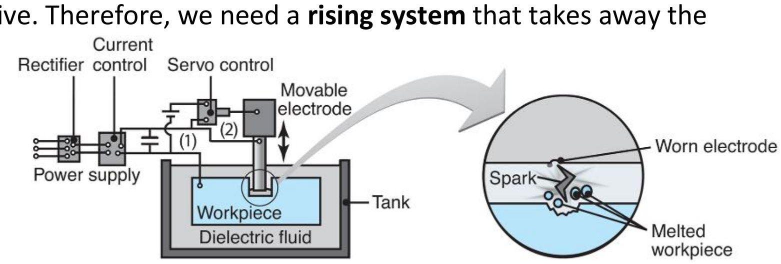


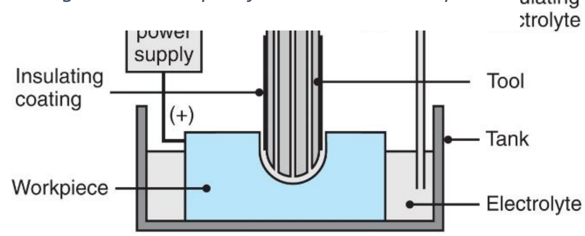
Figure 84: Electrical discharge machining

- **Materials with high hardness** (for the simple reason that the workpiece and the material will not touch. There will not be any force on the tool or on the workpiece).
- Complex shapes.
- Good geometric and surface quality.
- Low removal rate.
- Electrode wear.
- **Suitable for tool production (very often used)**.

Figure 85: Example of an EDM machined piece

Electrical-Chemical Machining

In electro-chemical machining (ECM) an **electrode is lowered into the workpiece** to shape it. In this case, the fluid is a salty saline electrolyte (**conducts electricity**). The material is dissolved electrolysis).



There are a few characteristics of ECM:

- **Product-related electrode**.
- Geometry inversion.
- Anode material liquefies by electrolysis.
- Electrolyte is conductive.

ECM has a **relatively high removal rate**. The removal rate is proportional to strength of the current, which ranges from 5-20v and more than 10.000 A. ECM has **limited accuracy** because the material is moved relatively fast. There is **no tool wear at al**. ECM suffers from environmental and corrosion problems. The liquids that are used are definitely an environmental hazard.

EDM is often to create a tool or very specific products, whereas **ECM can be used to create multiple products in smaller batches.**

Etching

Etching is also called **chemical machining**. We simply rely on the fact that we have an aggressive fluid, and that fluid does an **chemical attack** on our product. We do not have currents at all, just the fluid that will **eat away** the material. The whole process is just exposing the workpiece to the fluid at the right place. There are several characteristics:

- ‘chemical attack’; no current.
- Chemically aggressive fluids.
- No inversion of geometry.
- No electrode.
- No machining forces.
- **Machining of extremely thin workpieces possible.**
- No burrs.

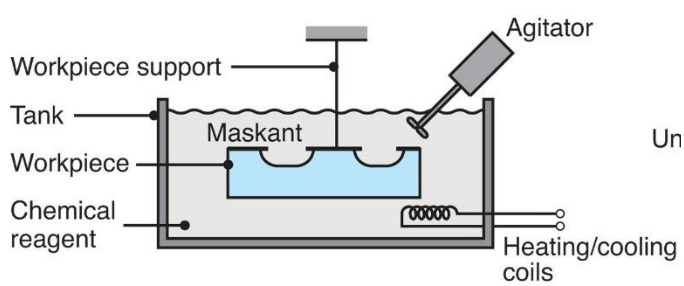


Figure 86: Etching process

Etching has a risk that some parts will be eaten away which are not meant to be eaten away. It is **hard to control process**. It is very important to determine the time that the material is under influence of the fluid.

Assembly & Joining

General & Fusion Welding

Often, the decision must be made about if the assembly will be put together **manually or with a robot**. That decision depends on the number of products. Robots can be the solution for some cases (think of repetitive work).

Joining processes that are detachable are processes with an "undo functionallity". You can unassemble the assembly. If you take away connective components, then your products are still there. A joining method can be **fully detachable, partially detachable, or not detachable at all**. For partially detachable joining, think of using staples. You could remove the staple and the paper stays more or less the same.

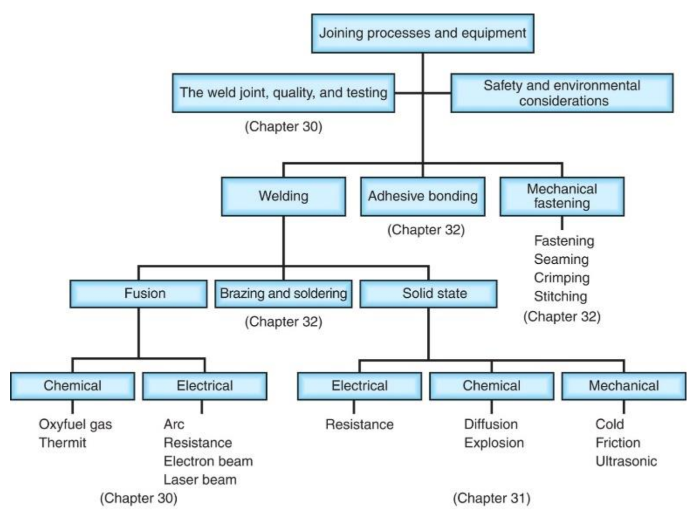


Figure 87: All joining processes

Another subdevision of joining are the principles we are using to connect the parts. Are we connecting geometry, do we use force to make them fit, or do we use material by for example melting the material.

Fusion welding

In fusion welding, we want to create heat with flames and "burning things". There are two main types of fusion welding:

1. **Oxyfuel-gas welding**. Method that uses only gas to weld.
2. Arc welding. Method that uses gas ***AND*** electricity to weld.

Solid state welding

In all these cases, we want to make sure that **locally the material heats up**, under such a temperature that the material will locally melt under the influence of electricity or friction forces.

Friction welding

Friction welding means that there are two components to connect. There is **one component that rotates, and one component that doesn't rotate**. When the components touch, the materials will kind of melt together, because of the enormous friction that has a lot of energy.

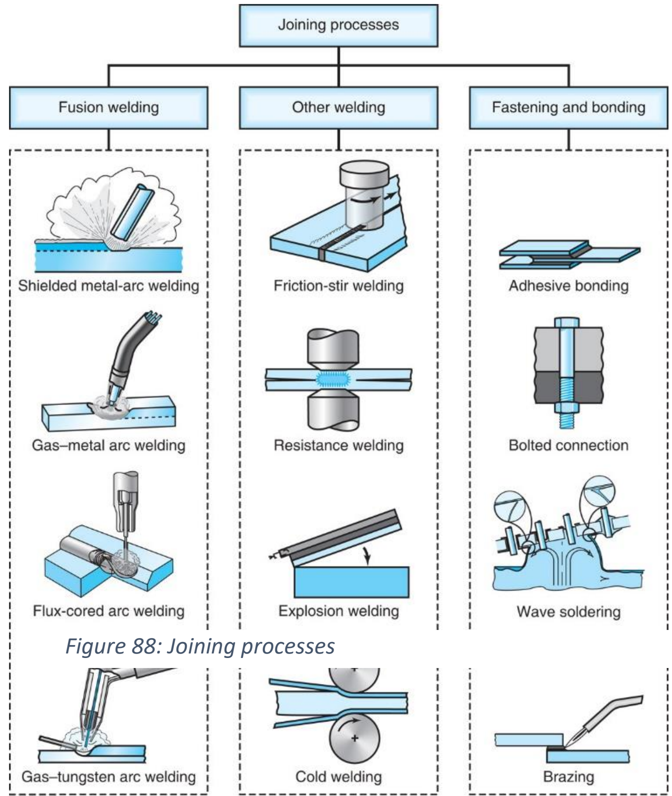


Figure 88: Joining processes

Oxyfuel-gas welding

In this case we simply have the gas mixture. The gas comes out of the torch. We set fire to the gas, and that causes the heat that makes the metal meld, and we add material with the filler rod. We are melting the filler material together, and then we add material out of the filler rod to fill up any voids.

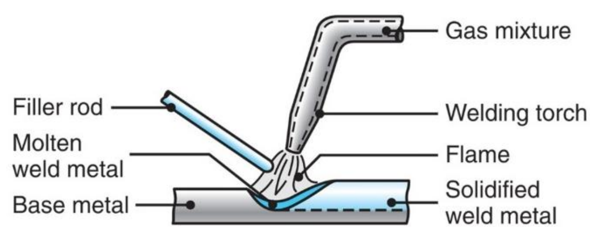


Figure 89: Oxyfuel-gas welding

The big advantages is that there is no electricity needed. The disadvantage is that it is not the most subtle process because you simply have burning gas that simply cannot be an extremely small flame. This will definitely not work for thin materials or precise assemblies, but it can be quite **good for construction work beams** etc.

*Tungsten-arc welding (**TIG**, tungsten inert gas)*

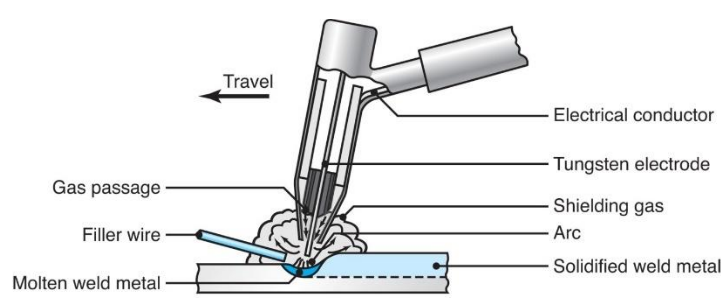


Figure 90: Tungsten-arc welding

Tungsten-arc welding is much **more subtle**. It is basically the **same as oxyfuel-gas welding.** In this case, there is a “tungsten electrode”. With that electrode, we make a voltage difference **between the material and the electrodes**. Because of that electricity in the arc, that arc will be much **more precise**, will give locally much higher energy and will melt the material and therefore welded together quicker. The electrode is made out tungsten (wolfraam). The **tungsten will not burn**, but only glow if there is no oxygen. That is what we need. Therefore, an **inert gas is used** that pushes away all the oxygen.

Plasma-arc welding

Plasma-arc welding is similar in a sense to tungsten-arc welding. It again has a tungsten electrode. Again, the inert gas pushes away the oxygen that we don’t want.

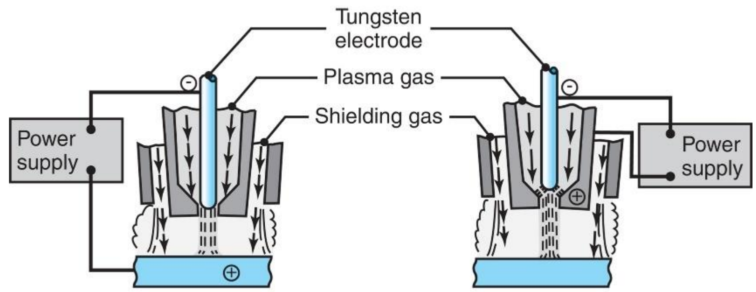


Figure 91: Plasma-arc welding

Shielded metal-arc welding

Shielded metal-arc welding is a more **traditional** way of welding. We have our base material and electrodes. In this case, the electrode is a specific one. The electrode is made out of the metal we are going to use to transfer the electricity to heat up the material. But, it contains a coating and that coating contains the small bubbles of gas that we need. So, the electrode will burn away and by burning away it releases the gas that we need. Big advantage, we **do not need additional filler rods or gas storage places**. The big disadvantage of shielded-metal welding is that you have to control the distance of the electrode. If your electrode **touches the material, it will meld together**.

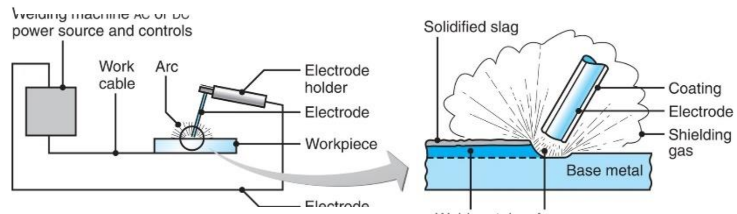
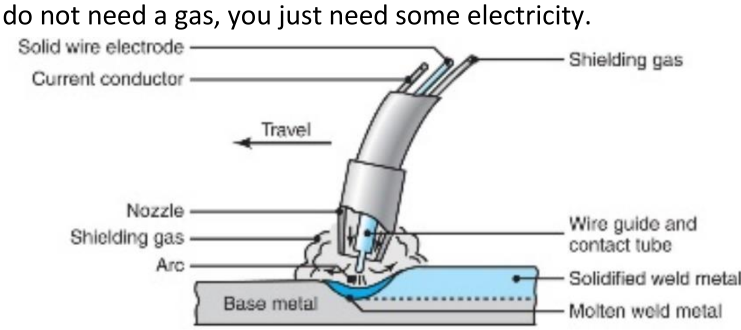


Figure 92: shielded metal-arc welding

This process is **extremely hard to automate**. You do not need a gas, you just need some electricity.

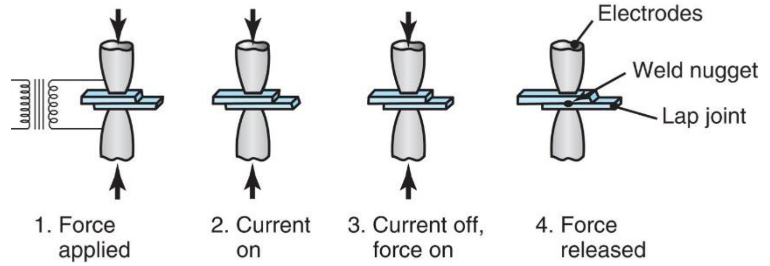
Gas metal-arc welding

In industry, gas metal-arc-welding is used a lot. We will use the arc, and we again have a torch which creates the arc that welds the base metal together. But, in this case we again have a solid wire electrode. It is not made of the tungsten we saw before. This type of material **will wear away** but because we know that the simple thing that we can do is having solid **wire on a roll, and simply push new electrode** towards where we’re welding on a continuous basis. For **automation processes**, it is much easier to use. There are two types of gas metal-arc welding.



1. **MAG** = Metal (electrode is made of metal), Active gas (**gas with oxygen**). It is used when there is as much heat needed as we can afford (ex. Tougher job). It is nothing more then any gas that contains oxygen.
2. **MIG** = Metal (electrode is made of metal), Inner gas (gas **without oxygen**).

Between MIG and MAG, the different types of gas is the only difference. Co2 welding is a type of MAG welding, but because it is used so many times, it is called Co2 welding.



Brazing, gluing & other joining processes

Resistance welding

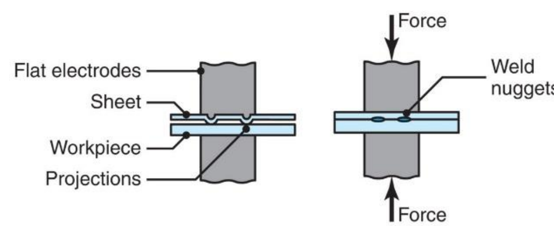
In resistance welding, we do not need any gas. We simply have two electrodes again. We place the material between two pieces of material, and forces and electricity is added to push the material together. Normally nothing will happen because everything is made out of metal, but because there is **electrical resistance**, there will be enough heat to melt the materials together.

It is a very fast process, but when it is done, it is **impossible to undo** the weld. So it is typically a non-detachable process. It is possible to position accurately the place where the welding is needed. It is **perfect for automation**. You can very locally place the weld.

It is important to make sure that the **material is not too clean**. Otherwise, the resistance will not be big enough. You need a little bit of dirt and inaccuracies to generate the needed resistance.

Projection welding

Projection welding is a variant of resistance welding. In this case we know that we are going to connect the product and fuse parts **in those individual spot** welds. What we could do is make small out carved spots to make sure that multiple spots can be welded at once.



Flash welding

Here we use a lot of force that pushes together two parts of material. In this case, they are both stable. Once they are **pushed together**, then we add a lot of force and then they are welded together. It is a very accurate connection as well.

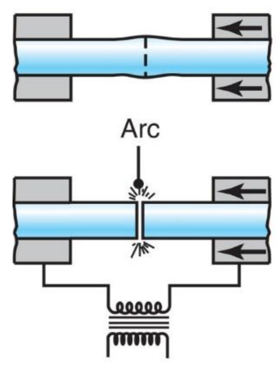


Figure 93: Flash welding

Explosion welding

 We have the base plate. On top of the base plate there is a clad metal. There will be a lot of explosive material on top of that with the detonator and then on the press of a button the material explodes and the explosion causes a force, which pushes the clad metal downwards. In that way we **force the materials to connect** each other. It will be more or less a geometry based connection.

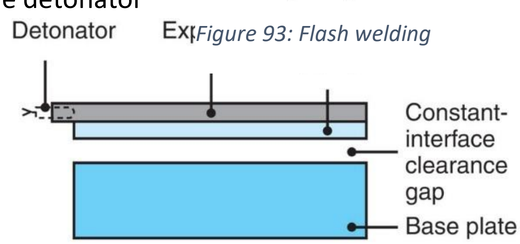


Figure 94: Explosion welding

Rivets

Rivets has to do with deforming geometry to keep things together. We have two components that we want to connect. We make sure that the two components both have a hole in them and those holes are aligned. Then stick a rivet through that. There will be forces on the rivet on 1 side. It has a **kind of a undo function**. The **softer your rivet will be, the easier** it will be to use.

<u>Joining faces</u>

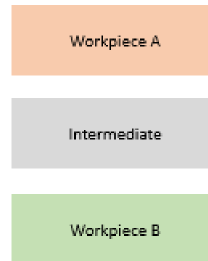


Figure 95: joining faces

When joining faces, there are two workpieces, they need not be of the same material and we have a kind of intermediate that connects the two so we also know that the intermediate is usually not that strong compared to the material of the workpieces. Also, the bigger the surface area of the intermediate will be, the stronger the connection. Basically, this is the definition of **gluing**.

The connection consists of two types of connections:

1. **Adhesion**. Strength of the intermediate material and the workpiece. (e.g. strength between glue and the wood).
2. **Cohesion**. Strength of the intermediate itself. (e.g. strength of the glue itself).

The best gluing techniques are those with **a lot of adhesion**, and as little intermediate material as possible. The intermediate is the weakest part of the joined part.

It is important to find ways to have big faces to join. That will strengthen your product.

***Brazing** and soldering*

Brazing and soldering is a way to join faces. The intermediate material is the tin. Due to **capillary action**, the tin will kreep into the material, making a larger surface area. The bigger the surface of the joined faced, the stronger the binding.

The main difference between brazing and soldering is the type of material. In soldering, tin is used. For brazing, materials like silver are used which are stronger and have a higher melting temperature.

Adhesive bonding (glue)

In gluing, we simply have two components and without usually heating them up, we add the intermediate material. Note that with different types of glue, there are different things to do. The intermediate (the glue) is very often organic material. The adhesion depends a lot on the material. In porous material, we often rely on mechanical bonding.

In plastics, we use the softening of the surface layer. We try to wake up the polymers on top of the plastics then we make sure they touch each other, and then the molecules will be entangled. For metals, you glue on the principle of the van der waals-forces.

Seaming

In seaming, two components are deformed in such a way that one **component is around the other**. Then you can have a very strong connection caused by the geometry of the material. It is very much **used in the production of tin cans**.

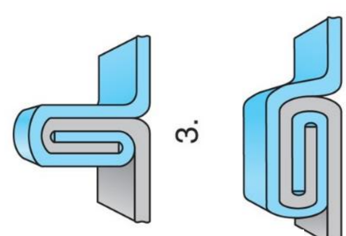


Figure 96: Seaming

Crimping

Crimping is a one way process and it is **not possible to separate the materials afterwards**. In general, there are two parts that does not fit quite well, one part is heating up and put on to the other part. **Because of the heat, the material will expand.** Therefore, the material will fit. After cooling down, the fit is very precise. That will require to much forces. Heating up 1 material is not possible anymore, because it is almost 1 part.

Plastics Processing

General & Extrusion

Plastic processing is very specific because most process for plastics is what we call **net-shape or near-net-shape**. That means that we **aim to make our product in one go**, in one process and immediately finish the product as it should be. We want to avoid making holes or machining it because every movement that we have to do with mass produced products would be very expensive.

Plastics

Plastics = polymer + additives

A polymer is in short nothing more then an extremely large molecule (many parts) consisting of a repetitive pattern. Polymers are expensive. For that reason and because we can change the behaviour of the polymer we want to add additives. For example:

- Plasticizers for flexibility and softness.
- Anti-scission. Protect against ultra-violet radiation and oxygen.
- Fillers. Cost reduction by adding sawdust, sand, chalk.
- Colorants. Dyes.
- Flame retardants. Chlorine, bromine. Make it more resistant to fire.
- Lubricants. Reduce friction and sticking during processing.

If we look at plastics, there are three main types:

1. **Thermoplastic** materials (TP). Thermoplastics will become viscous when heating it up, in that way it is easy to deform it.
2. **Thermosetting** materials (TS). Thermosetting materials will disintegrate when heating it up, deformation is not possible
3. **Elastomer** materials (E). The rubbery materials.

Composite

Composites are a combination of two or more chemically distance and insoluble phases with a recognizable interface. It is a specific type of plastics where we do not only see the plastics and the additives but **also a kind of fibre** that will give us a special product quality. Together it is called a **composite material**. There are different types of fibre:

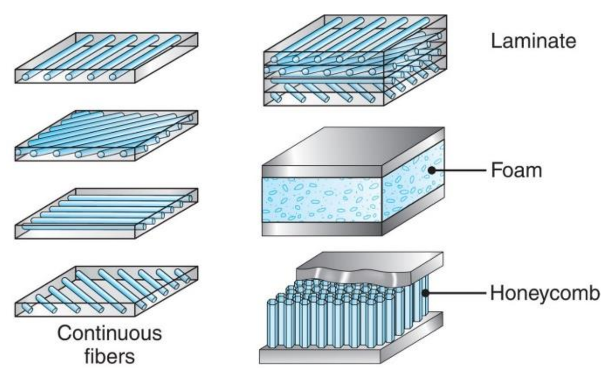


Figure 97: Composites

1. **Glass fibre.**
2. **Aramids.**
3. **Carbon fibre.**

The fibres (usually in one direction) are embedded in the plastics. Because the fibres are in 1 direction, the material is also only **very strong in one direction**. Therefore, many times the producer makes sure that the plastics are strong enough in the opposite direction of the fibres.

Composite material will have very different material qualities in different direction. For that reason sometimes many layers of composites are used, which is called laminate.

Extrusion of plastics

In extrusion we take our material, we push it through a die or a mould, and that will give us the needed shape (compared to a tube of toothpaste). You can easily make complex products. Note that this process is **only possible with thermoplastics and elastomers**, not with thermosetting materials because they will disintegrate when heating it up, and heating up the material is needed for viscous plastics.

In the extrusion of plastics we start with a starting material (**mostly granulite**). The granulate is placed in the hopper (a container that stores the material until we use it). The screw of the machine pushes the material forward (**doesn't move itself**), the pressure will slowly increase. The heating mechanisms of the screw will slowly melt the plastics. When the material meets the die, it will be formed in the right way. The **production of hollow materials is also possible**.

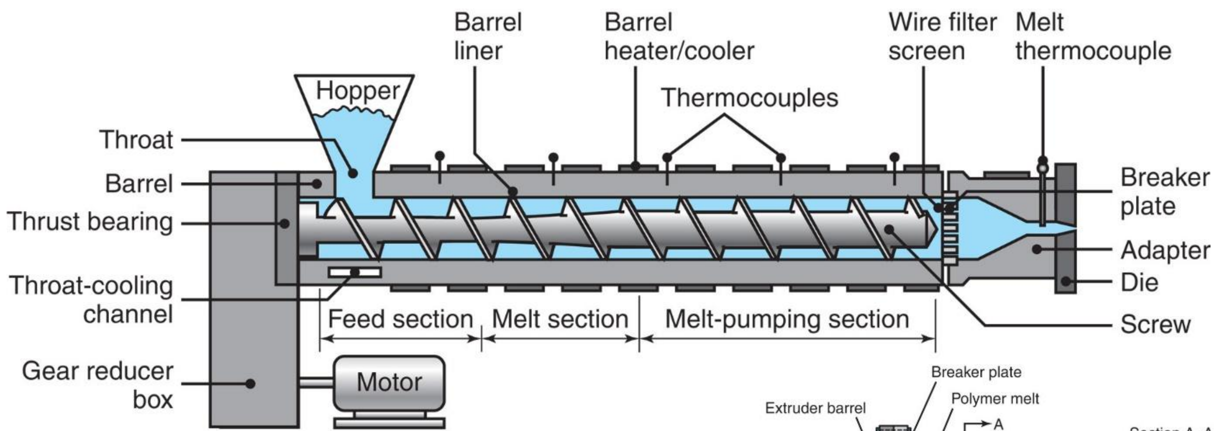


Figure 98: Extrusion of plastics

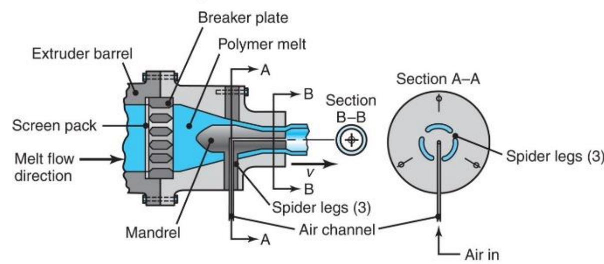


Figure 99: Detailed view of the die

Co-extrusion of plastics

Very often we need material that consists of **two types of plastics** (e.g. tubes with different layers). That is what we can do with co-extrusion. In that case we have two extruders, each of them responsible for a specific type of material.

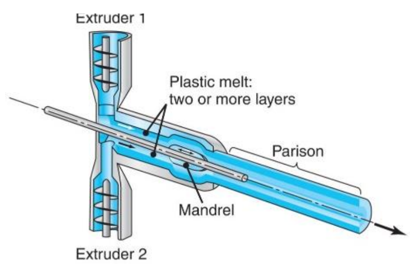
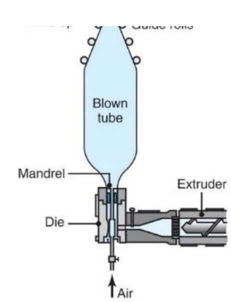


Figure 100: Co-extrusion of plastics

Extrusion followed by blowing

In this case we use a normal extruder, but instead of making a continuous product, we bend around the product and add air to the insight of the product. **Immediately as the product comes out, we start cooling the material**. The air provides pressure to blow up the tube. We wait till the product is cooled down, guide the product by the roles and after that we wind it up. This is the **production process of plastic bags**. In reality, the machines to do this can be very big.



General note: You will **never make plastic products in small batches**!

Injection moulding

Injection moulding is used a lot, especially in the consumer industry. In injection moulding, we have a mould and we fill it with a material. The filling of the mould will be done under a **very high pressure** (70-200 Mpa). That pressure is so high because the plastic needs to be viscous and that is hard to handle. There are a few advantages of injection moulding:

Figure 102: Products made with injection moulding

1. **High accuracy.**
2. **Good surface quality possible.**
3. **Possibility to make very complex products**.

Exam Alert!

Injection moulding is only possible with viscous materials, but it is possible for thermoplastics, elastomers , ***and thermosetting materials***. Thermoplastics are easily to heat up and make viscous, but also thermosetting materials have to be made once for the first time. That "creation" of the thermosetting material will be done in the injection moulding process.

Injection moulding of plastics

Injection moulding looks a bit like extrusion. Again we have a hopper which pushes the granulite into a screw. The screw wil push the granulite forward, while doing that it will become viscous. The volume of the screw will be bigger to the end of the machine. Therefore, the pressure is increasing. In the end we want to push our material into the die.

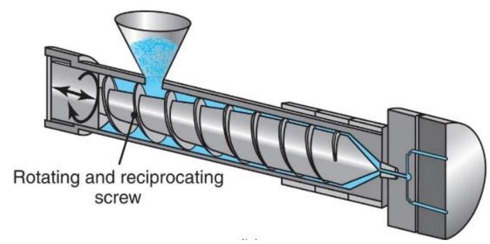


Figure 103: Moulding machine

The main difference between injection moulding and extrusion is that during the screwing process, the **screw moves backwards** and makes space for the exact amount of needed material. After that, the screw is pushed forward with a very high pressure that will fill the mould with the exact right amount of material. If there is too little material, there will be a lot of air bubbles, if there is too much, the machine will continue pushing.

If you look at a plastic products, you will almost always see spots. The material is still hot when it will be pushed out by **ejection pins** (cooling down very much will require too much time). Therefore, the spots are easily visible.

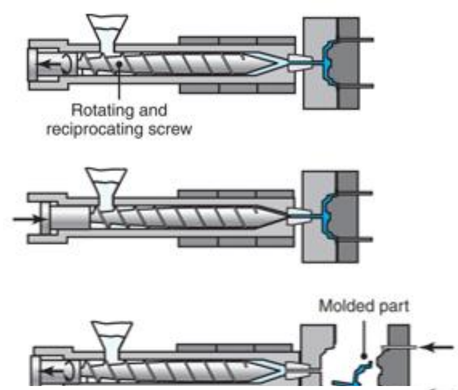


Figure 104: Moving screw

In injection moulding, dies have to be of a very high quality. Every quality issue of the die will be seen in the product. In many dies, there are cooling methods used. That will speed up the moulding process. Because of the quality and the cooling methods, the **dies will be very expensive**.

2k injection moulding

In 2k injection moulding, we make a product with **two different materials** of the same type. It is possible to make a product with two or more materials in one go.

Simulation

Simulation of the moulding process is **very important**. You have to know the possible fails before making the mould because moulds are very expensive. In this way, knowledge can be gained on the production process that can be used for optimizing the process.

Production of multiple products at a time

The more products that can be produced with one injection, the cheaper the product will be. Also the production of the sprue (figure) is a loss of material, so that has to be done as little as possible. Therefore, we can use **combined injection mould** which can produce multiple products in 1 go as can be seen in the figure.

The smaller gates are used to increase the pressure when injection.

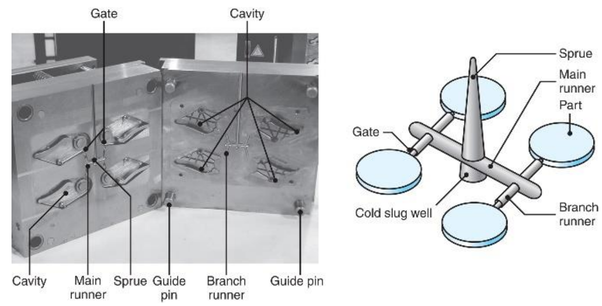


Figure 105:Combined mould

Rotational moulding, blowing and other processes

Rotational moulding

In rotational moulding we can make large products with very big geometries in plastics. A disadvantages is that there is a considerable **variance in wall thickness** and because it is a fairly **slow process**, we do it in smaller batches.

A big advantage is the possibility to make **hollow products**. We start with a mould, we pour in the plastic material, then we close the mould, rotate the mould and the plastic will stick to the wall of the mould. When opening up the mould, there is a hollow product. The inside of the product will be a bit unpredictable. We might have different wall thicknesses and less quality on the inside.

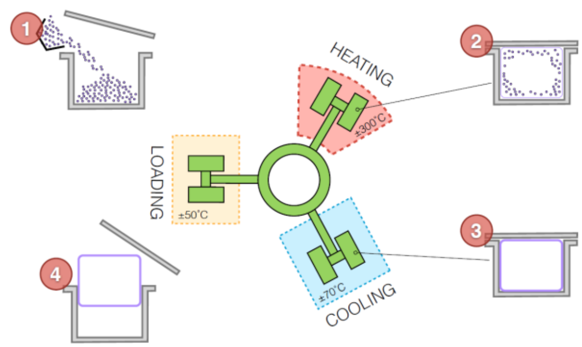


Figure 106: Process of rotational moulding in four steps

Rotational moulding is only possible with thermoplastic materials.

There is no **high pressure or high forces** needed. There is just a little bit of rotation and heating up needed. Therefore, making a mould that consists of multiple parts is easily possible. In that way, it is possible to make products that look like you cannot get them out of the mould. The mould will also be not too expensive.

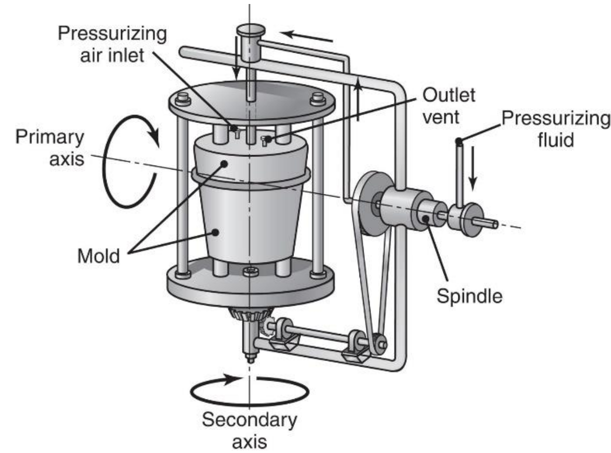


Figure 107: Moulding machine

It is possible to make openings in the product. If you make parts of your mould out of material that does not stick to plastic, there will be an opening.

A goal of rotational moulding is to rotate the mould as randomly as possible. In rotational moulding, you will **not find injector pins** because the process is not very high speed. You can find **multiple parting lines**, because the mold can consist of multiple parts.

Extrusion blow-moulding

In extrusion blow moulding, the extruder creates a plastic tube. Then the specific mould will cut off the tube by closing. Then, the blowing pin blows air in the tube and the tube will expand.

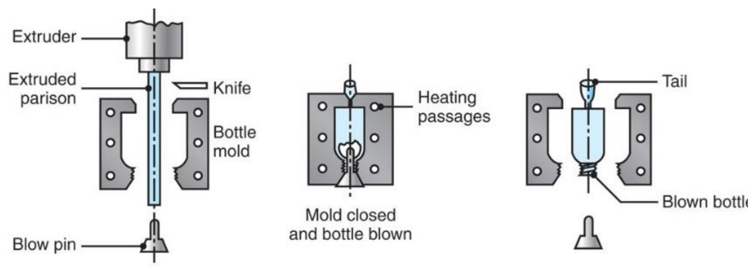


Figure 108: Extrusion-blow moulding

After that, the mould is removed and a product made by extrusion blow-moulding can be used. In extrusion blow-moulding, the bigger the diameter will be, the thinner the wall will become. It is only used for a large batch, so simulation will be needed.

It is typical for extrusion-blow moulding that the **surface thickness is not the same everywhere**, especially sturdy faces on the top and the bottom.

Injection-blow moulding

In this case, we make a very small shape of what we actually want in an injection moulding machine. After that, we put the injection moulded product in a bigger mould with a blowing pin, which will blow up the product.

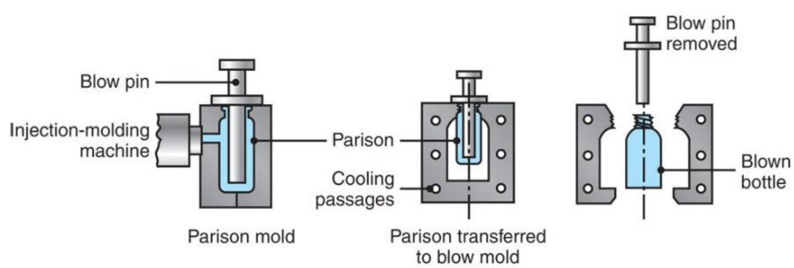


Figure 109: Injection-blow moulding

It is typical for injection-blow moulding that the **surface thickness is the same everywhere** and that it is possible that there are **very sharp corners**. Injection blow moulding is **more precise, but also more expensive** because of an extra step. Again, there are expensive dies so simulation will be needed.

***Three-station** injection blow-moulding machine*

The transport of empty bottles is a very expensive process since you are carrying around mostly air. Therefore, many times the bottles are filled at the same place as they are manufactured.

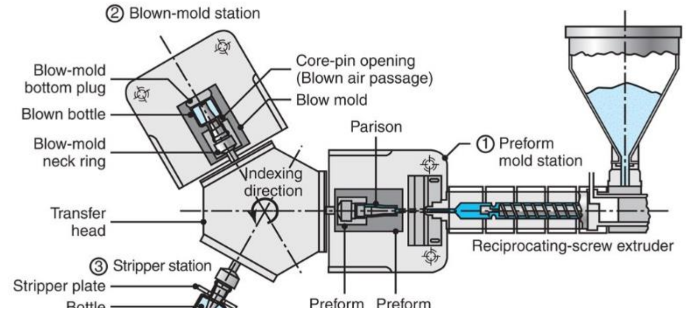


Figure 110:Three station injection blow machine

Foil/Film/Sheet

In the production of foil, film, or sheet, we are using a process that is called calendaring. In calendaring we have **several hot rollers**. The incoming material will stick to those rollers and the thickness will be decreased by the rolling process.

Again this process focusses on **thermoplastics** because the plastic needs to viscous to fulfil this process.

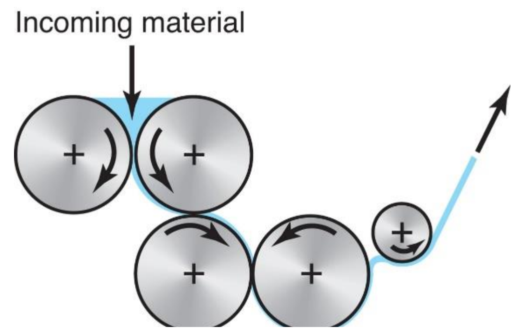


Figure 111: Calendaring

Thermoforming

In thermoforming, the base material will be a foil or a sheet of **thermoplastics**. That sheet is heated up until it becomes deformable. After heating it up we will use a die and a vacuum line (or pressure) to create the form that we want. There are hardly any big forces, so that means that the moulds can be very cheap. But, again we will have **different wall thickness**.

Usually, the products that are made by thermoforming are **disposable and cannot be used for ages**.

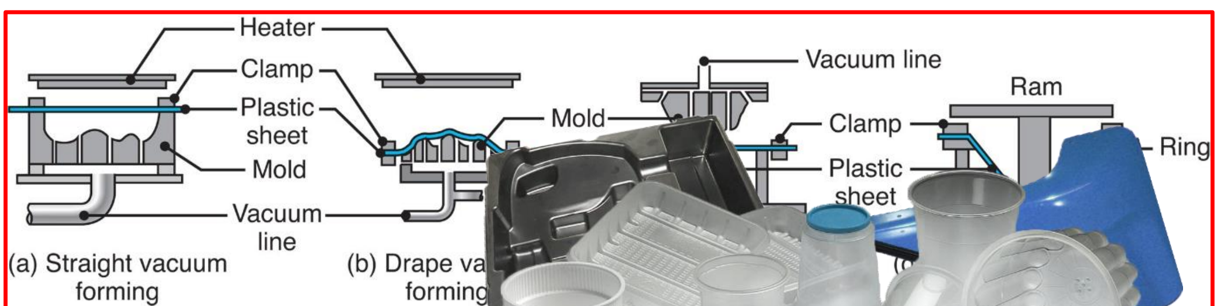


Figure 113: Thermoforming


Figure 112: Thermoformed products

Additive processes (sort of 3D printing)

Additive manufacturing are processes where we have a group of technologies that grow three-dimensional objects, one (thin) layer at the time. They all have the same principles:

1. **Fast start of production**. We only need the material or the machine, we do not need any tools.
2. All process gradually build the product. The product is **build layer for layer**.
3. Relatively **low production speeds**. Therefore, additive manufacturing focusses on small batches.

It is very important that we have the material where we need it. That can be done by engendering of material. That can be done in several ways:

- Local **polymerisation** of resins.
- Local **solidification** of metal or plastics.
- Local **sintering or gluing** of grains.
- **Stacking of foil material**.

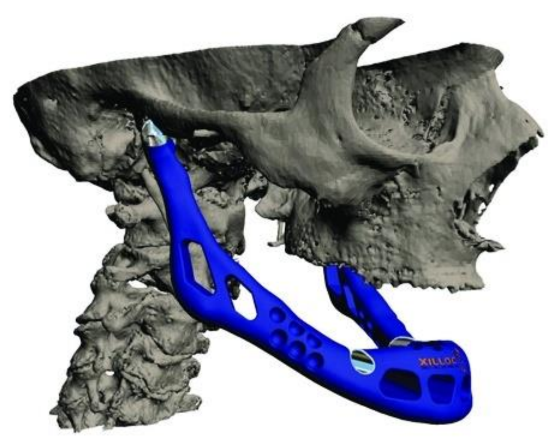


Figure 114: Products made with additive manufacturing

It is possible with additive manufacturing to make very specific products. Think of prostheses or other very specific products. Other characteristics of additive manufacturing are:

- **No advantage to scale**. Once the design is made, making a single item can cost – per piece just about as much as making many.
- **Complexity is 'free'**. The technology can manufacture complex items that are very difficult or even impossible to make with extractive technologies. The geometry is unrelated to the process. You can manufacture extremely complex items without a big increase of cost.
- **Speed up design**. Owing to the ability to manufacture "one-offs," engineers can try many different designs and test them before an item is released to manufacturing.
- **Customization**. Unique items can be made to exact fits, be it custom clothes or custom replacement body parts. It is very specializable.
- **Efficiency**. There is almost zero waste.
- **Weight reduction**. It is possible to reduce weight and only create strength where the strength is needed.

Topology optimisation = optimize the geometry by giving strength to the product where it is needed, and removing it where it is not needed. It can save a lot of material. It can made by a simulation if the forces are known. The simulation will optimize the part, but only for the specific simulated process.

Stereolithography

Stereolithography is a production process. There we have a platform in a vat, and that contains a liquid and that liquid is a very specific type. If we **shine on the liquid with a concentrated UV light, the liquid hardens out**. Simply by shining light on the liquid, locally that liquid will turn into a polymer, a solid material. That is called **local solidification**. A product can be made layer by layer by lowering the platform. As soon as one layer is finished, we lower the platform.

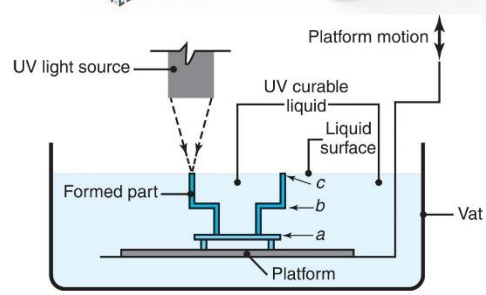


Figure 116: Stereolithography

It is very important that the solidified product has more or less the **same density as the liquid,** otherwise the solidified product will sink. There are no forces in this process, except for the force of gravity.

Fused deposition modelling (normal 3D printing)

In this case we have a wire, called filament which is basically a thermoplastic material. We feed the plastic into the heated build head which will heat up the wire. It is possible to draw a plastic model by moving the heated build head by a machine which moves in the x-y plane. The table moves in the z-direction.

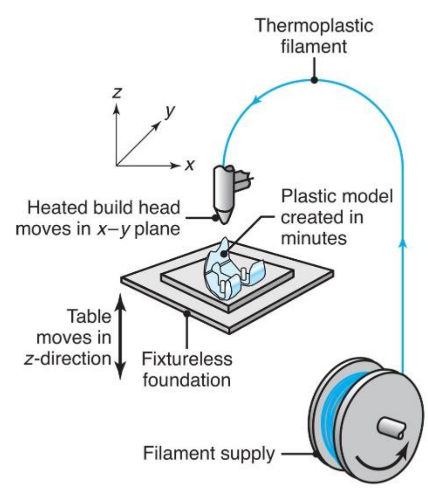


Figure 117: Fused deposition modelling

It is only possible to start the production on top of existing geometry. For that reason we very often don't only have our product, but we also have what is called support filament. That means that in these printers we very often have two types of material. A filler material (cheapest as possible), and a material that is used for the product.

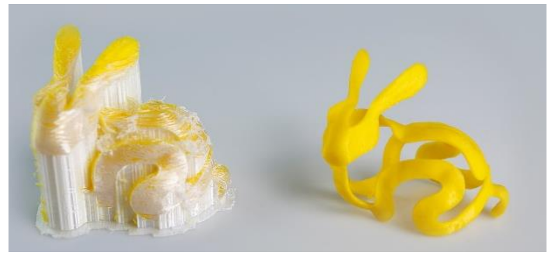


Figure 118: Support filament

Selective laser sintering

In selective laser sintering, we use a building table. There will be a **layer of powder on the table, and the laser will be used to locally synthetic the material**. We literally bake the gates of material together. Once we did that for a layer, we lower the part-build cylinder.

It is a lot used for products that **need topological optimization.** In that case, it is very important to watch out for enclosures so your powder can actually be released.

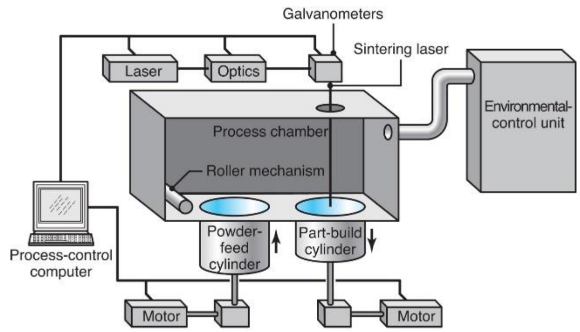
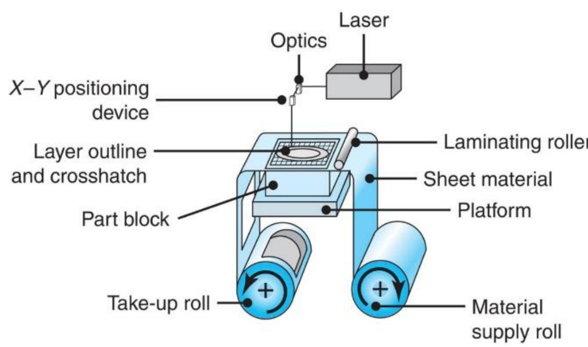


Figure 119: Selective laser sintering

Laminated object manufacturing

We have one layer of material which we **locally glue together** to the previous layer. We cut out what we need, put a new layer on top of it, and do the same thing over and over again. This process **will take a while to complete**.



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Surface quality

The surface quality of a product produced with additive manufacturing process will be lower on top of the product, then on other places. The printed layers will be visible on top of the product. This is called the **staircase effect**. It can be reduced by making more and thinner layers, but that is not always possible.

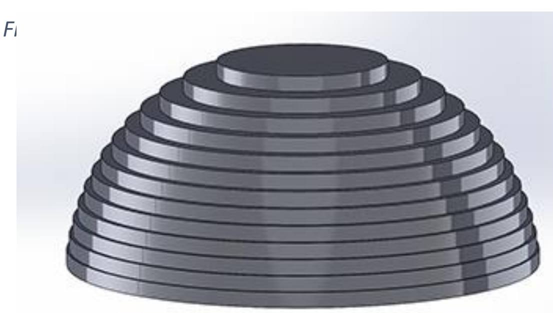


Figure 121: Staircase effect

Hybrid manufacturing

In hybrid manufacturing, we combine different processes. We first of all use a process to engender the material that we need, and then we use in the same machine tools to get the accuracy where we want it (to get the quality that we will need).

Summary 3: Technical product modelling (TPM)

Norms

We have different types of norms. Those norms are

DIN (German Industry Norm)

ISO (International Organization for Standardisation)

ASTM (American standard)

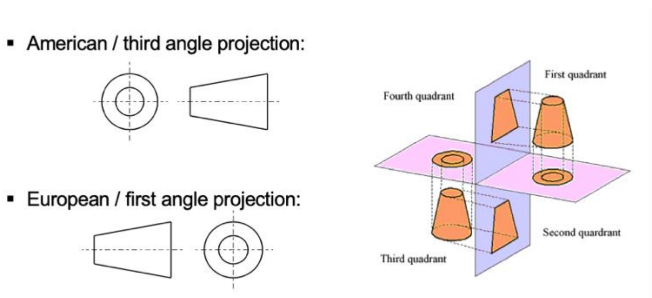
NEN (Dutch norm)

Projection methods

Orthogonal projection method

Product is viewed orthogonally (true forms and dimensions are clear directly)

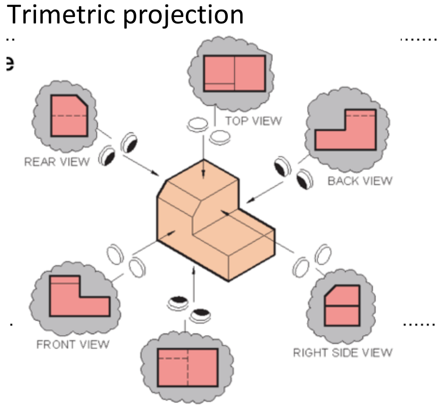
- American projection / third angle -> most applied method in NL
- European projection / first angle



Axonometric projection method

Product is viewed from the perspective view

- Isometric projection
- Dimetric projection
- Trimetric projection



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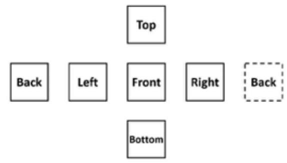
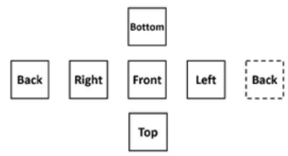
- American projection (third angle)



- European projection (first angle)



Line types

We also got different line types. The first line is the solid line, this is a visible boundary line. We also got thin solid lines, those lines are used for dimensions, as auxiliary lines, hatching, thread or the center of circles. Lastly, we got the dashed thin lines, those are used as non-visible boundary lines.

The second type of lines are the thin centerlines. At the end those lines are thickened also used as section view lines. We also got the non-thickened centerlines. Those lines are used for shafts and holes.

Section views

Section views are used with non-massive products because section views clarify the internal geometry of a product. Section views are hatched (thin parallel lines) basically under 45 and 135 degrees. With one part the hatching is in one direction, and with an assembly the hatching angle is different when parts are adjacent.

Distance between the lines refers to the relation of the section area. Section view arrows are closed and filled arrows. Section view lines are thin centerlines that are thickened at the end.

There are some exceptions with regard to hatching. For example, spherical massive parts; like ball bearings and long cylindrical parts in the longitudinal directon.

Drawing types

We have different types of drawings. First, we have the detail drawing, where the component is fully defined, can be produced with the information on the drawing. The second type is the assembly drawing. The assembly drawing shows how all the parts go together in the assembly. Identification numbers and dimensions between the parts are shown. A combination of both drawing is also possible.

Layout 2D drawing

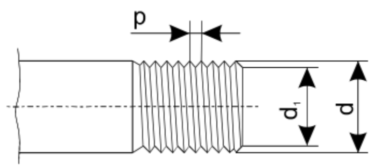
A drawing consists of the following elements

- Title block / strip
- Necessary projected views
- Use views if the projected view can be placed in line with the parent view
- Section views; to clarify the internal geometry of the product
- Details; if a small part of the product has to be enlarged

- Parts list if drawing is assembly drawing

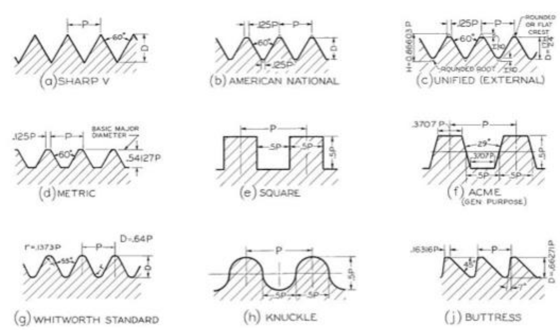
Guidelines

- Use hidden lines just with simple products
- Use centerlines with shafts and/or cylindrical parts
- Use center marks (vertical and horizontal centerline) to indicate the middle of a circle
- Do not sketch or show tangent lines
- If possible, use scale 1:1, 2:1 (for enlargement) or 1:2 (for reduction) is the preference when 1:1 is not possible

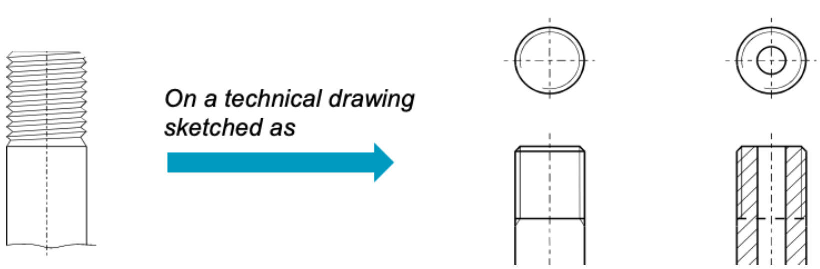


- d / D – major diameter;
- d1 / D1 – minor diameter.
- p – pitch; top-top distance.

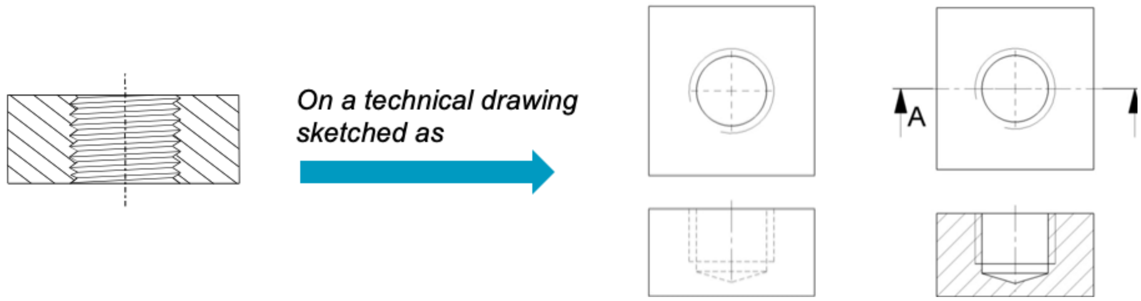
Bolts, screws have external thread, whereas nuts have internal thread. Various forms of threads are used to hold parts together, to adjust parts with reference to each other, or to transmit power. Unless otherwise specified, a thread is considered a right-hand thread. A RH thread advances into a nut (internal thread) when turned clockwise. Left-hand thread is always labeled LH on a drawing. Advances into internal thread when turned counterclockwise.



When we want to sketch external thread, we draw a thin ¾ circle at the inner side. When we draw in the front view or section view, we have a thin solid line at inner side.



When we are going to sketch internal thread, we have to draw a thin ¾ circle at outside of circle in the top view. When we have the front view, we have a thin dashed line at the outside of the hole. And in the section view, we draw a thin solid line at the outside of the hole.

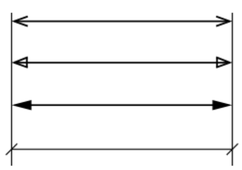


Two rules; the external thread is always placed in front, and bolts and nuts are not sectioned.

Dimensioning

Ofcourse, if we are busy with sketching, we should also look at dimensioning. There are different arrows on a dimensioning line. Dimension lines should not cross, and dimension and extension lines should also not cross. Extension lines may intersect. Dimensions must be readable from the bottom or right side. Dimensions must be placed outside the view, if possible.

Dimensions should be placed in the middle between the arrows, otherwise arrows to the outside, or extend dimension line to the side and place dimension there. Place dimensions above the dimension line



Indicate fillets from center point fillet and an arrow towards the fillet. Indicate angles with a circular arc. A small chamfer (45 degrees) is indicated with dimension x 45 degrees. We also got some symbols that are important with dimensioning, those are the following:

Ø for diameter;

R for radius;

□ for a square;

AF (across flats - 2 flat faces on a cylindrical product);

hex. for a hexagonal fo

Important is to capture the product in as little views as possible. In dimensioning a single part, its relation to mating parts, must be taken into considerations. Those dimensions, common to both parts, are mating dimensions.

Dimensional tolerances

It is impossible to make anything exact to size. Actual dimensions will always vary from the exact dimensions due to machining. What degree of accuracy is needed for the functional requirements? For this, we need a specification of a tolerance on each dimension. A higher accuracy means more expensive manufacturing processes which means higher costs. For example, if we have a nominal size of 50, and we have limit dimensions 49,7 and 50,1, then we have a tolerance of 0.4.

We also got different tolerance types. The first type is the symmetrical tolerances, which are given in numbers 50+-0,05. The second type is the fit tolerance, which is given in a letter plus a number, 50 H6. Bilateral tolerances mean that the lower and upper range are different.

Without any tolerances, a bolt can or cannot be assembled, with the tolerances given a bolt can always be assembled.

Fit tolerances

Tolerances should be as big as possible, but as accurate as needed, otherwise the company will make unnecessary costs. Sometimes it is necessary to have an accurate relationship between two components. A fit tolerance is a very accurate relation between 2 components (mostly shafts and holes). There should be a desired clearance between mounted parts.

Fit system

A fit system is a system of tolerances aimed at a certain function of the parts; therefore, interchangeability of parts is also possible. A system of standardized tolerances called the International Tolerance grades are often used.

Fit is the relation between mating parts, depending on the clearance value.

Basic terms

Basic size is the nominal diameter of the shaft and the hole. This is, in general, the same for both components. Limit dimension; the outer values of the dimension; the real dimension must lie in between these values. Deviation is the difference between limit dimension and basic size.

Fundamental deviation is the limit dimension with the smallest deviation; limit dimension closest to the basic size. Fundamental deviations are labelled with a letter. Capitals for holes: A-Z, and lowercase letters for shafts: a-z.

Internation tolerance grade, the so-called IT grade is a standardized measure of the maximum difference in size between the component and the basic size. Size of the tolerance is labelled with a numer

1-4: accurate

5 – 11: normal

12-16: rough

There are two methods of coupling holes and shafts. First, we have the basic hole system. The lower deviation of the hole is always equal to zero, labelled with “H”, for instance 10H7 /s7. We also have the basic shaft system. The upper deviation of the shaft is always equal to zero; labelled with “h”, for instance 10 S7 / h7.

The basis hole system is mostly applied, but why is that the case? Holes with a fit tolerance have to be reamed. Special tools for this are needed. With the basis hole system just H-reamers are needed, otherwise A-Z reamers. Shafts with a fit tolerance can be produced more easily.

Clearance fit : 10H8/d10

Transition fit: 10H8/j7

Interference fit: 10H8/n7

Basis hole system; because hole has the H

35 H6

- Lower limit
- Tolerance field: IT grade 6
- Upper limit

35 p5

- Lower limit
- Tolerance field (IT5)
- Upper limit

Surface roughness

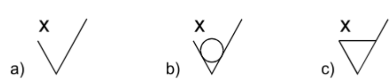
Funtion of the part requires

- Dimensional accuracy
- Form accuracy
- Surface roughness

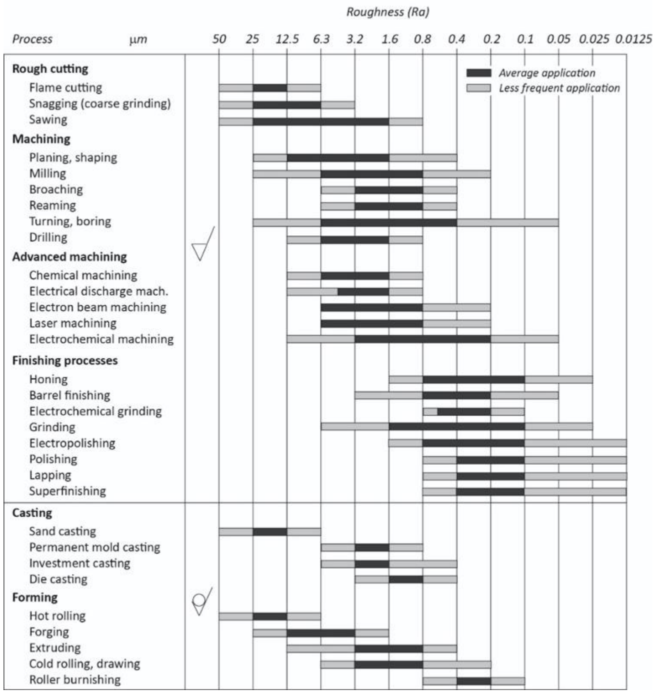
Surface roughness is the component or surface texture, it is determined by the production method. Roughness Ra in um. Quantified by the deviations in the direction of the normal vector of a real surface from its ideal form. Large deviations mean a rough surface, whether small deviations mean a smooth surface.

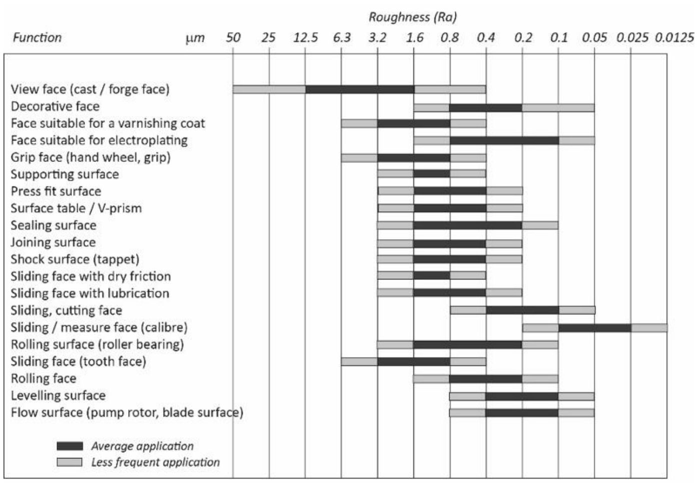
Symbols for surface roughness are

a. Basic symbol (arbitrary process);
b. Process without machining;
c. Process with machining.



Where x is the roughness value



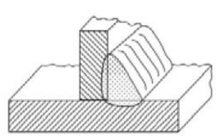


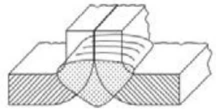
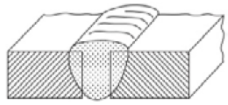
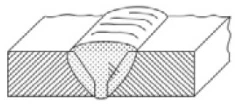
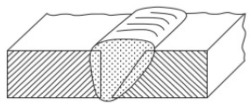
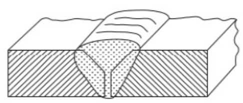
Surface roughness can be determined in two ways; one with the function of the surface, or with the way of production. The function of a surface determines the roughness of that surface. Thereafter, this makes the choice for a certain production method. Surface roughness as rough as possible, but as small as needed for the function of the surface.

Welding

Welding joins materials, usually metals or thermoplastics by causing fusion or using pressure in conjunction with heat. Some weld forms and welding symbols are displayed below

fillet weld



Designation	Illustration	Symbol
Butt weld between plates with raised edges (the raised edges melt down completely)		
square butt weld		
single-V butt weld		
single-bevel butt weld		
single-V butt weld with broad root face		

A fillet weld is indicated with an “a” or “z” value, where a is the leg dimension and z is the throat dimension.

Geometric tolerances

Geometric tolerances define the allowable variations in form and possible size of individual elements and allowable variations in form and size between elements. Geometric tolerances are used because fit tolerances, dimensional tolerances or surface roughness are not always enough to define accuracy of a product.

Feature	Type of tolerance	Characteristic	Symbol
Individual features	form	straightness	⏤
		flatness	⏥
		circularity	○
		cylindricity	⌭
individual or related features	profile	profile of a line	⌒
		profile of a surface	⌓
related features	orientation	angularity	∠
		perpendicularity	⊥
		parallelism	//
	runout	circular runout	↗
		total runout	⌰
	location	position	⌖
		concentricity	◎
		symmetry	⌯

Geometric tolerance is given with a symbol, a tolerance value and a reference element.

Summary 4: Product Market Relations

Lecture 1 - Introduction

Knowledge clip 1A – What is marketing?

Marketing: The activity, set of institutions, and processes for creating, communicating, delivering, and exchanging offerings that have value for customers, clients, partners, and society at large.

- Marketing is about creating value. Marketers are value engineers.
- Marketing is about identifying human and social needs.
- Marketing is about getting it right.
    - Design within context.
        - Marketing was changed a lot by the use of e.g. social media. Now, people are buying products from all over the world instead of only from local stores.
        - Marketing is also changed by the awareness of sustainability → Balancing people, profit, and planet in the right way. Companies are currently *getting* that balance *right*. The companies that are not getting it right are really struggling at the moment.
        - At the moment there are A LOT of new products being developed. While younger people are better at adapting to all those products. Older people need a bit more help with adapting. That is where marketing has a big role → How can we help consumers through our marketing?

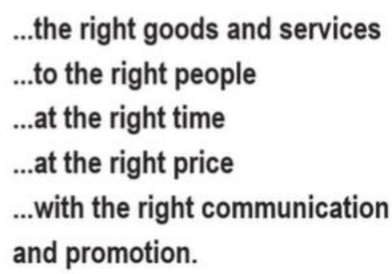


Figure 122: Getting it right in marketing. Marketing engineering is combining all these elements.

Value: Benefit. The value you get from a product.

Marketing management: The art and science of choosing target markets and getting, keeping, and growing customers through creating, delivering, and communicating superior customer value.

Knowledge clip 1B – Core marketing concepts

Difference between needs wants and demands. Needs become wants when people are directed to specific objects that might satisfy the need. Demands are wants for a specific product backed by an ability to pay. *(See figure 2)*

Marketers do not create needs. Needs pre-exist the market, marketers create products consumers might want.

- *People did not want Facebook, but they had the need to communicate, this need was translated into a want by Facebook.*

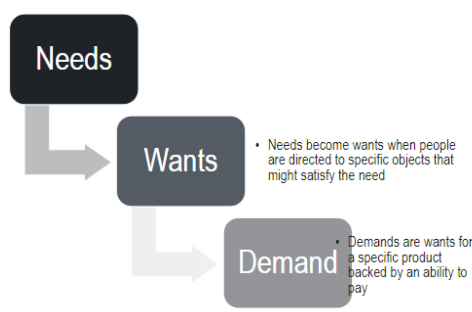


Figure 123: Needs wants and demands

STP (Segmentation, Targeting, and positioning)

- Segmentation: Splitting up the market into different segments.
    - Based on demographics or lifestyles.
- Targeting: Target the segments with the greatest opportunities.

- Positioning: To stand out in this target market, get in the minds of the people in this target market.

Value proposition: The type of value that the company plans to create for target consumers.

- A set of benefits that satisfy the needs.

Customer value triad: Based on three elements used for value.

- **Price.** Has a negative relation to value.
- **Quality.** Has a positive relation to value.
- **Service.** Has a positive relation to value.

Supply chain and marketing channels:

- Supply chain: The whole process from raw materials to final user (the final buyer).
- To get to the final user there are three channels.
  - **Communication channel**
  - **Distribution channel**
  - **Service channel**

Knowledge clip 1C – Marketing design

Marketing is not accidental, it is designed and planned.

Marketing is a design science and a design practice. So, we have a design thinking perspective on knowledge. A design thinker always has several steps:

1. Discover what is there with the users.
2. Synthesize all of that into a problem statement.
3. Design solutions for that problem statement.
4. See if the solutions work and deliver them to the market.

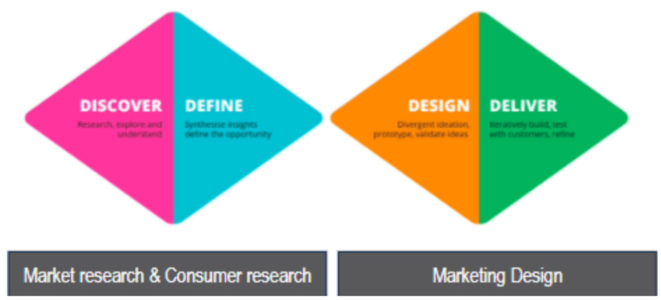


Figure 124: The 2 phases of a design thinker in 4 steps.
Discover: Research, explore, and understand.
Define: Synthesize insights, and define the opportunity.
Design: Divergent ideation, prototype, validate ideas.
Deliver: Iteratively build, test with consumers, and refine.

These steps are combined in 2 phases. Market research and consumer research (analyzing to see for what we can design something) and marketing design. Critical in design thinking is keeping the customer's point of view in mind.

Figure 125: The marketing mix.

From design to plan

- Marketing mix: 4 Ps.
  - Product: What products am I selling?
    - The packaging is an important part of the product.
  - Price: What is the value of the product that I am selling?
  - Place: Where the consumer can buy the product.

        - Where you interact with the consumer.
    - Promotion. How does the promotion fit the product?
- Has to be in line with the complete idea of your product or service. Design within context.

Customer point of view and …

marketing myopia

Marketing myopia: When an organization has a narrow-minded marketing approach and when the organization is focusing more on the needs of the organization than on the needs of the customer. This can lead to a company missing the boat. *(See figure 6)*

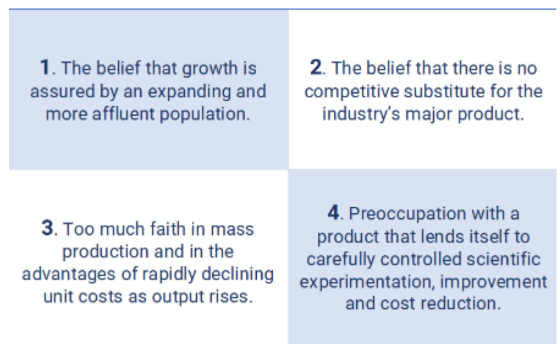


Figure 127: Marketing myopia is seen within 4 different elements.

Think different

The whole point of marketing myopia asks us to think differently. Examples of different perspectives:

- Volkswagen. It is not in the car industry, but it is in the mobility industry.
    - The company is analyzing competition based on **market orientation.**
- "People don't want to buy a quarter-inch drill, they want to buy a quarter-inch hole." Theodore Levitt (the founder of marketing myopia).

By thinking differently like in these examples, you are looking from a customer perspective and constantly looking at the value of your product. How can we create value for our customers?

Lecture 2 – The company: Strategic marketing and branding

Within the marketing plan, there are 3 elements.

1. First, to write a marketing plan, you have to understand the market. Understanding the company, all kinds of trends and developments, and well everything (analyzing the market a bit).
2. The strategic marketing plan is about choosing the value.
3. Based on the strategic outline, you make a tactical marketing plan. In which you provide and communicate the value (based on the 4 Ps).

Knowledge clip 2A – Customer value and marketing strategy

Perspectives on marketing.

- We used to have a <u>transaction perspective.</u> Firms make something and sell it to consumers.
  - Push-strategy.
- Around the 80s / 90s this turned into a <u>relationship perspective.</u> Firms and consumers are having a relationship with each other.
  - Concepts such as loyalty and branding became important.
- Nowadays we speak of <u>value perspective.</u> Firms create value for consumers (setting the value straight).
  - <u>Pull-strategy</u>: Pulling customers in by them seeing the value that is added by the product.

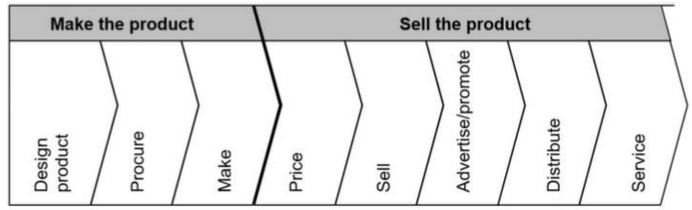


Figure 128: Traditional marketing process.

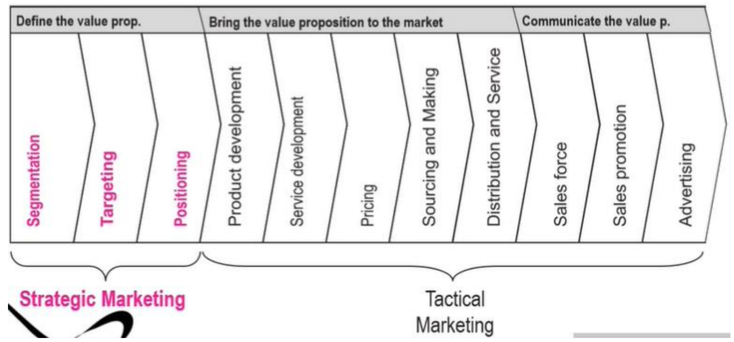


Figure 129: Value-based marketing process.

  - 3 steps
    - First you have to choose the value (define the value proposition). Done by STP (Segmentation, Targeting, Positioning).
    - Second, you have to actually provide the value (bring the value proposition to the market). Done by 3Ps of the 4Ps. Product, Price, Place.
    - Third, you have to communicate the value. Done by promotion.
  - Mastering the value chain by planning. Combining everything into a marketing plan, the central instrument for directing and coordinating marketing efforts.
    - The marketing plan has 2 levels.
      - <u>Strategic marketing plan:</u> Set out your strategy. Showing the value that you planned. This is the first step of the value-based marketing process (STP).
      - <u>Tactical marketing plan:</u> Providing and communicating the value. How and what you do. These are steps 2 and 3 of the value-based marketing process.

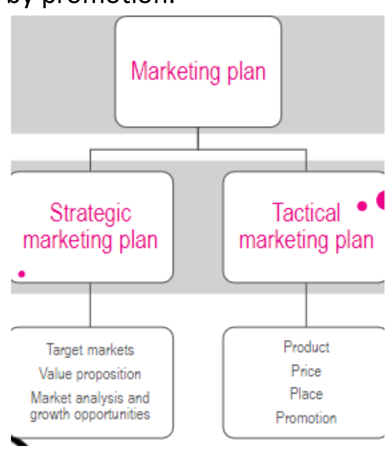


Figure 130: Levels of a marketing

  - Mastering the value chain by thinking differently.
    - Market definition vs. product definition.
      - E.g. Is the **company** (Paramount pictures) selling a **product** (movies) or a **market** (entertainment)?
      - E.g. Is Miele selling washing machines or clean laundry?
    - It all starts with the why.

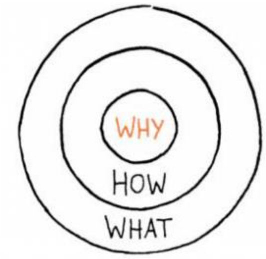


Figure 131: The golden circle

- The golden circle: Why, How, What. Every organization knows WHAT they do (the products or services they sell). Some know HOW they do it (the things that make them special/set them apart from the competition). Very few know WHY they do what they do. Why does the company exist? The answer is not to make a profit, this is a result. Why is a purpose, cause, or belief.
    - Simon Sinek
- People don't buy what you do, they buy why you do it. Reverse the order of giving information. From why to what. Not from what to why.

Core competencies – Characteristics

When talking about a company, it is good to have clear insights into what its core competencies are.

- Delivering your competitive advantage → What makes you outstanding compared to the other companies that offer likewise products/services?
- A real core competency is something that is difficult to imitate. What makes the company unique?

Knowledge clip 2B – Writing a marketing plan

A marketing plan consists of 2 parts → Strategic marketing plan and a tactical marketing plan.

A marketing plan always has a specific layout.

- Start with the executive summary. Even though you write this part last.
- First the strategic marketing plan part.
    - **The company.** The internal organization, the why of the company Vision, mission, values, positioning of the company, SWOT, Brand identity, Brand-image, POP&POD.
        - SWOT: Analysis in search of opportunities. From analysis to strategy. Can be positioned in any chapter of the strategic marketing plan.
    - **Competitive environment.** Competition, Macroenvironment, Trends, and developments.
    - **Target audience.** From segments to targets, Demographics, and Personas/Tribes.
    - **Positioning.** Value proposition canvas.
        - Customer profile: The customer has some things he/she wants to get done. Some lead to gains others lead to pains.
        - Value map: The products and services the company delivers, and if those are

Figure 132: SWOT analysis.

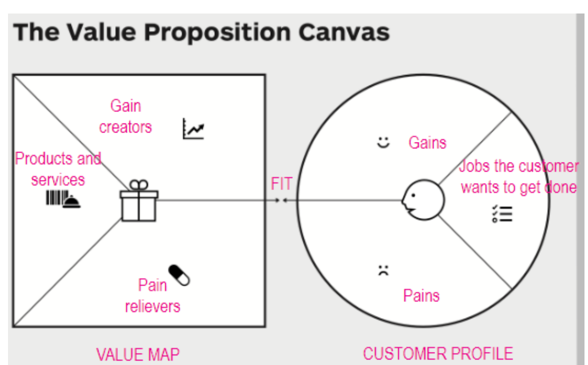


Figure 133: Outline of the value proposition canvas

gain creators or pain relievers.
        - Helps to get a good fit between the customer perspective and the products and services of the organization.
- Then continue with the tactical marketing plan. How to execute the marketing strategy you set up?
    - **Product.** Prerequisites, Ideation process, Prototyping, Sustainability.
    - **Price.** Pricing strategy, Final price.
    - **Place.** Distribution strategy.
    - **Promotion.** Promotion strategy, Examples of marketing communication.
- **Financial projection.** Can be done in different scenarios/risk analyses.
    - Sales forecast
    - Expense forecast
    - Break-even analysis.
- **Production summary.**

Knowledge clip 2C – Brand positioning

Brand positioning belongs to the STP framework.

Positioning (of the brand): The act of designing a company's offering and image to occupy a distinctive place in the minds of the target market.

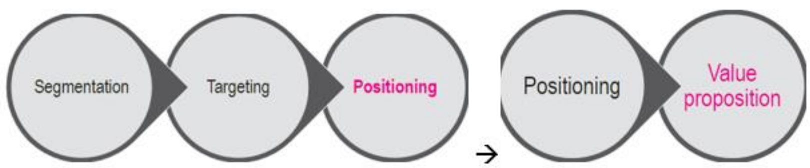


Figure 134: STP framework.

- A good positioning process leads to a value proposition. A cogent reason why the target market should buy a product/service.
- 3 steps in positioning.
    - Choosing a competitive frame of reference.
        - Map the crowd. To which brands are we going to compare ourselves? And to which brand do we consider ourselves laying outside the scope?
        - Competitors: Companies that satisfy the same customer need. It is more than being in the same industry.
        - When you have chosen your competitors you can start to compare them based on some set criteria.
    - Identifying potential points of difference (PODs) and points of parity (POPs).
        - POD: Attributes or benefits that consumers strongly associate with a brand, positively evaluate, and believe they could not find to the same extent with a competitive brand.
        - POP: Attribute or benefit associations that are not necessarily unique to the brand but may in fact be shared with other brands.
            - Category POP: Represent the necessary conditions to belong to a product/service category.
            - Correlational POP: Potential negative associations that arise from the existence of positive associations for the brand.

        - *Cheap prices can be positive but a negative association with it is bad quality.*
    - Competitive POP: Associations designed to overcome the perceived weakness of the brand in the light of competitors' points of difference.
  - Emotional branding: PODs and POPs that appeal to both the head and the heart.
- Creating a brand mantra. Not necessarily the same as your slogan.
  - A 3-5 word articulation of the heart and soul of a brand.
  - A slogan is a way how you communicate the brand mantra.

Knowledge clip 2D – Building strong brands

Brand equity: The value of the brand.

- What makes customers want to pay more for some brands than for others?
- The added value endowed to products and services.
- 3 related items.
  - Customer response
  - Brand knowledge
  - Brand perception
- A specific group of brands is interesting, the brands that we love → Strong brands in the brain:
  - Create more activity in brain areas associated with emotion and less in brain areas associated with reasoning.

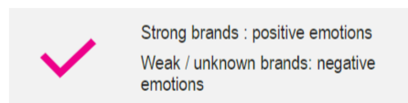


Figure 135: Strong vs. weak brands and emotions

Branding

Brands have a strong influence on our life, but we are not always aware of it. *Why are we willing to pay much more for a white t-shirt with a Nike logo on it than for a white t-shirt without a logo?* Most consumers are not just buying a product, they are buying a brand. A lot more than a product can be branded. A city, person, or concept for example.

Figure 136: The branding of Amsterdam.

The concept of branding changed during the industrial revolution. People used to buy all of their products locally. With the introduction of steam power and mass production, products were suddenly made somewhere else, transport was used way more. People did not know where their products were coming from anymore. So, brands started putting their name on their products.

Figure 137: Brand evolution timeline.

Brands can have a lot more impact than we think. *Red Bull for example. It tries to set an image with its slogan "Red Bull gives you wiiings", and by being involved with crazy sports like formula1. The brand gives you wings and makes you perform really well.*

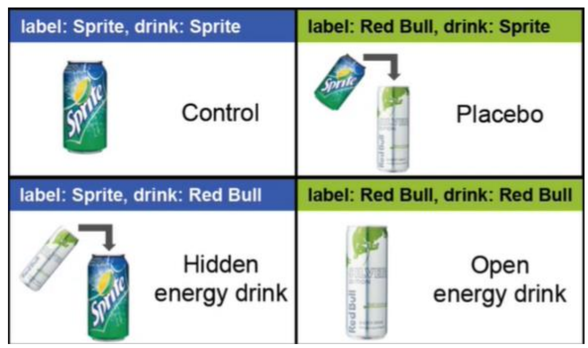


Figure 138: Experiment on the placebo effect of a brand.

In an experiment, Red Bull silver was compared to sprite (the taste is similar). The experiment used 4 scenarios (see figure 17). Students were asked to do a difficult assignment and if they believe they would pass the test → It mattered, not what they were drinking, but what they thought they were drinking.

Brand war: War on coke

Coca-Cola vs. Pepsi. In general, Coca-Cola is winning this brand war. Not because they have a better product, Pepsi has the better product. The Pepsi paradox → People like the taste of Pepsi more when tasting blind, but still prefer Coca-Cola. This is because Coca-Cola has been selling the same concept for over 30 years. The concept of taste and happiness. Pepsi has done something else. They focused on the new generation. They have involved different famous people in their campaign. Pepsi tries to communicate that Coca-Cola is for the old generation and if you are from a younger generation, you drink Pepsi.

Coca-Cola is much better at addressing positive emotions in the brain. Which is why we love the brand Coca-Cola more than Pepsi. Now, Pepsi is also trying to focus more on making you smile.

Figure 139: Brand archetypes.

Personality of a brand – Archetypes

Brands are almost considered real people/identities. One way to map to this is by looking at brands as archetypes. Not every brand has to really stand out and be trying to catch the news. Some brands (like Hema, Zeeman, and Johma) are really strong in being an 'easy' brand.

Customer journey

Customer journey: A journey that a customer has in which all the touchpoints with the brand are visualized based on experience. Touchpoints: All the elements of contact with the brand. It is about customers' experience at those touchpoints. Touchpoints can be inside a shop and outside a shop.

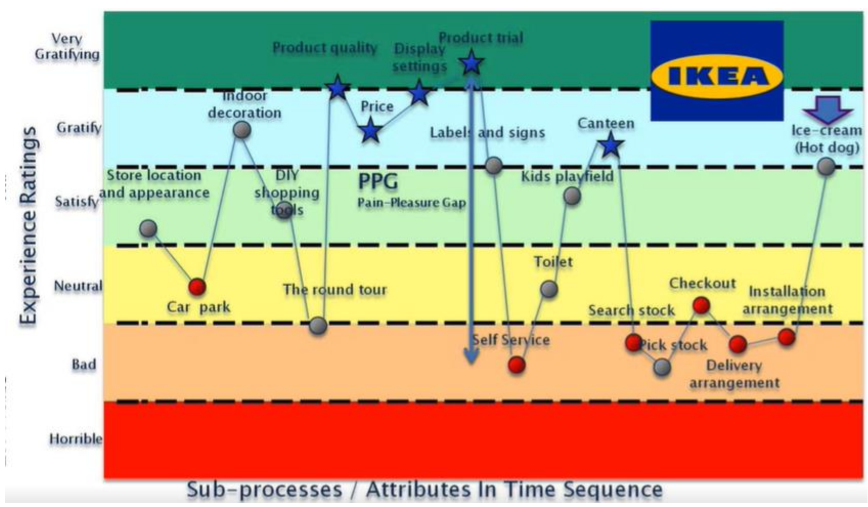


Figure 140: Example of all the touchpoints during the IKEA shop experience.

Brand extensions

Brand extension: A brand that is normally selling a certain product is now selling a different product under the same brand name. If it all fits right, brand extensions work really well.

- Advantages:
  - Improved chance of success.
  - You do not have to invest in branding as much because the product can already lean on the original brand.
  - Positive feedback (contamination).
- Disadvantages:

- Brand dilution (if not aligned with the proposition). When people do not understand what the brand is doing all of the sudden.
- Negative contamination.

Brand identity: The internal stakeholders' self-perception.

Brand image: The external stakeholders' perception.

Knowledge clip 3A – Marketing intelligence

There is a reason that marketing intelligence has been a hot topic in the past decades. The marketing discipline has evolved from a more traditional perspective (focusing on the push strategy) toward a more value-based perspective, the pull strategy. This change created a need for marketers to have more inside into the need of customers.

- Nowadays, there is a need for a set of data regarding marketing intelligence. Data-driven marketing.
  - Consumer Insights: The needs and behavior of the consumers.
  - Consumer feedback
  - Trends and developments.
    - Specifically regarding fast technology developments.
  - Information about competitors.
  - Market information.
- Marketing metrics & Marketing dashboards: A set of measures that help to quantify, compare and interpret the marketing performance.
  - Every marketing expert works with these metrics and dashboards.
- Marketing forecasting & the rise of neuromarketing: Seeing marketing from the response in the brain of the consumer. Activation in particular parts of the brain can predict what type of product or advertisement will work.
- The value lies not in the data itself, but in what you do with the data.
  - Decision making
  - Product development
  - Creating value

Figure 141: SWOT

Knowledge clip 3B – Macroenvironment

Before being able to properly make a marketing plan, you need to have a good understanding of the market, consumer, and environment. The results of creating this understanding will mostly be presented in a SWOT analysis *(see figure 20)*.

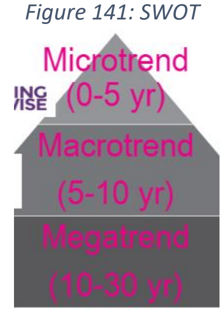


Figure 142: Trend pyramid.

- 2 ways to present the microenvironment (in this knowledge clip).
  - Time perspective *(figure 9)*.
    - Collect different types of trends and put them in a pyramid. There are a lot of websites to collect these trends. The trends have to be relevant to your topic.
      - *The shift in economic power from west to east is an example of a **megatrend**. It affects on a global scale.*
  - Topic perspective

- DESTEP analysis *(figure 22).*

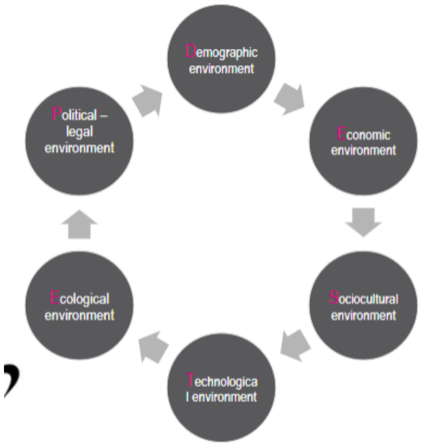


Figure 143: DESTEP analysis

  - **D**emographic environment
    - Information on population, household patterns, and generation issues.
  - **E**conomic environment
    - Inflation, interest, (un)employment, and general trust in the economy.
  - **S**ociocultural environment
    - Subcultures, important values in society.
  - **T**echnological environment
    - New technology, new innovation opportunities.
  - **E**cological environment
    - Circular economies, planet.
  - **P**olitical-legal environment
    - Business legislation, political atmosphere, political trust.

Knowledge clip 3C – Marketing research

<u>Marketing research:</u> The function that links the consumer, customer, and public to the marketer through information. This information is used to identify and define opportunities and problems; generate, refine, and evaluate actions; monitor performance; and improve understanding of it as a process.

- Specifies the information required to address these issues, designs the method for collecting information, manages and implements the data collection process, analyzes the results, and communicates the findings and their implications.
- 2 elements in the definition
  - What the marketing research tries to do. Why?
    - Marketing research is all about collecting insights. These insights lead to marketing success.

Figure 144: Marketing research

    - E.g. without marketing research you could redesign your packaging, but this new packaging is not an improvement according to your customers.
  - The process of conducting marketing research is a 6-step procedure. *Figure 24*.

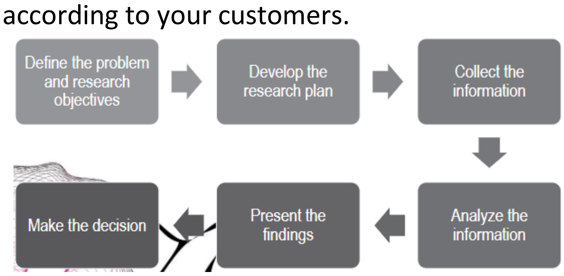


Figure 145: Process of conducting marketing research

    - Defining the problem → Determining your research question.
      - What is the goal of your research?
      - Types of market research.
        - <u>Exploratory:</u> Identify the problem and suggest solutions.
        - <u>Descriptive:</u> Accurately quantify demand.
        - <u>Casual:</u> Testing cause-effect relationships.
    - Develop the research plan → List a couple of things.
      - Data sources

- Primary data: Data gathered for this research project.
    - Secondary data: Data already collected for another purpose.
- Research approaches
    - Observational research, focus groups or interviews, surveys, behavioral data, and experiments.
- Research instruments
    - Questionnaire, qualitative research techniques, neuro techniques, Big data & data mining.
- Sampling plan
    - Population vs. sample, sample size, sampling procedure.
- Contact methods
    - Online, in person, by mail, or by telephone.
- When doing consumer research by questioning, mind the following aspects:
    - Ensure the questions are free of bias.
    - Make questions simple.
    - Make questions specific.
    - Avoid jargon, sophisticated words, and ambiguous words.
    - Design a logical line in the interview or survey.

- Collect the information
- Analyze the information
- Present the findings
- Make the decisions

Knowledge clip 3D – Competition and growth

The lower half of the SWOT analysis is for competition and growth. Growth: Taking opportunities and making them an opportunity for growth. Is it necessary to always strive for growth?

Different strategies how to achieve growth. Product-market growth framework (Ansoff matrix) pictures 4 relevant strategies *(see figure 25)*.

- **Market Penetration Strategy**. For an existing product and an existing market.
    - Encourage customers to buy more.
    - Branding & customer loyalty.
- **Market Development Strategy.** For an existing product and a new market.
    - Identifying new user groups.
    - Additional distribution channels.

Figure 146: The Ansoff matrix.

- New locations (at home or abroad).
- **Product Development Strategy.** For a new product and an existing market.
    - New product features.
    - New combinations or offerings.
    - Innovation.
- **Diversification Strategy.** For a new product and a new market. There are 3 types of this strategy.
    - Concentric Strategy: New products that have synergies with existing product lines.
        - E.g. Disney already had their theme parks and then came out with the Disney channel, a new product on a new market, but it has synergies with already existing Disney lines.
    - Horizontal Strategy: Produce complementary products.
    - Conglomerate Strategy: New business with no relation to current business.

Growth and competition. When talking about growth strategies, you cannot forget about what the competition is doing.

- Trying to increase your market share (and lowering the market share of the competition).
- Takeover or work together with competition: mergers and acquisitions.
- Innovating: Try to be less dependent on the strategy of the competition (be aware of imitation by competition). Staying ahead of the competition.

Growth strategies also depend on the product life cycle.

- Usually, companies have a different growth strategy in each product life cycle phase.
- **Introduction phase.** Creating product awareness because nobody knows your product jet.
    - Product → Usually, in this phase companies offer a basic product.
    - Price → They charge cost-plus pricing methods.
    - Place → They use only a few distribution channels (selective distribution).
    - Promotion → They invest most of their money in promotion to create awareness among early adopters.

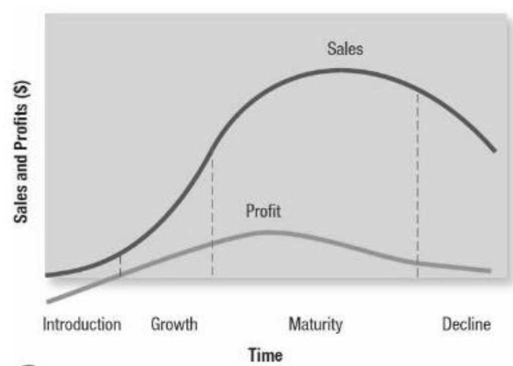


Figure 147: The product life cycle.

- **Growth phase.** Maximize market share. The market penetration strategy is most dominant in this phase.
    - Improve product and develop extensions.
    - Price to penetrate the market.
    - Intensive distribution.
    - Create awareness in the mass market.
- **Maturity phase.** Maximize profit while defending market share. This phase is all about branding.
    - Diversify product offerings.
    - Beat competitors' prices.
    - Intensive distribution.
    - Stress brand differences and encourage brand switching.

- **Decline phase.** Reduce expenditure and harvest the market.
    - Phase out weak products.
    - Cut price.
    - Phase out unprofitable outlets.
    - Reduce promotion to the minimum needed.

Knowledge clip 3E – Consumer behavior

What influences consumer behavior?

- Cultural factors
    - Hofstede's dimensions of culture.
- Personal factors
    - Age and stage in the life cycle.
    - Occupation and economic circumstances.
    - Personality and self-concept.
    - Lifestyles and values.
- Social factors
    - Reference groups.

Modeling the consumer response.

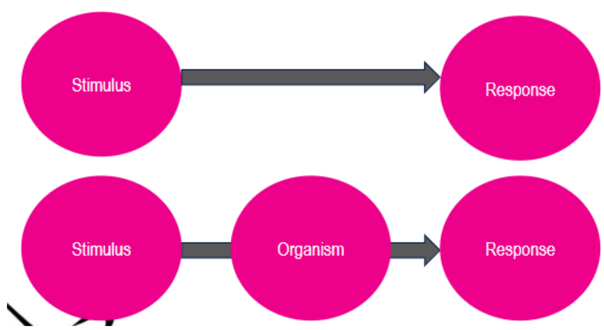


Figure 148: 2 consumer response models.

- People used to think of this as a stimulus-response model.
- Nowadays, stimulus-organism-response models (SOR models).
    - Stimulus: For example a higher interest rate or a commercial.
    - Organism: What does the stimulus do with the organism?
    - Response: What will be the response of the organism (consumer)?
    - In this model the consumer is seen less as a black box compared to the stimulus-response model.

Consumer psychology

- Key psychological processes influencing customer behavior.
    - Motivation. 2 important theories

- Maslow's hierarchy of needs. Behavior is driven by the lowest, unmet need (on the pyramid). Where you are on this pyramid is creating motivation for your behavior.

Figure 149: Maslow's hierarchy of needs

- Herzberg's two-factor theory. Behavior is guided by dissatisfiers and satisfiers. ***Z factor theory.***
    - Satisfiers: Elements that make you actively satisfied. (a swimming pool at a hotel.)
    - Dissatisfiers: If a feature is not there it makes you dissatisfied, but if it is there it doesn't make you actively satisfied. (Wi-Fi in a hotel room.)

- Perception. Nobody can perceive everything, so our attention is selective. Our perception is bounded. We use all kinds of cues that guide our attention.
    - One of the most important cues that people use is faces. Then, where the face of the other person is looking at.
    - Trust cues people look for are the smile, attractiveness of the face, and the facial width-to-height ratio.
    - Confirmation bias: Focusing on elements that confirm our thoughts. Seeking confirmation over information.
- Learning
- Memory

Knowledge clip 3F – Market segments and targeting

STP framework is repeated and explained in more detail.

- Segmentation: Dividing a market into smaller segments of buyers with distinct needs, characteristics, or behaviors that might require separate marketing strategies or mixes (4Ps).
    - Market segment: A group of customers who share a similar set of needs and wants. As a company, you want to address this specific want in a specific way.
        - Geographic segmentation
        - Demographic segmentation

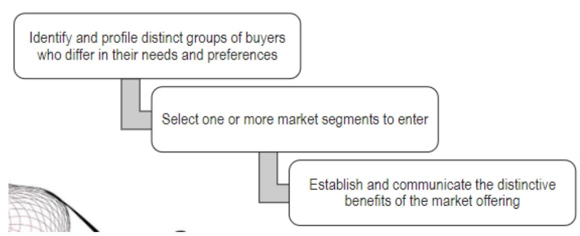


Figure 150: STP framework

- Psychographic segmentation: Segments based on lifestyles or values that people have.
  - Psychographic: Whether they were interested in something.
  - Vals framework: 8 different types of consumers (innovators, survivors, thinkers, believers, achievers, strivers, experiencers, makers). Each type has its specific lifestyle aspect and therefore also specific consumer behavior.
- Behavioral segmentation

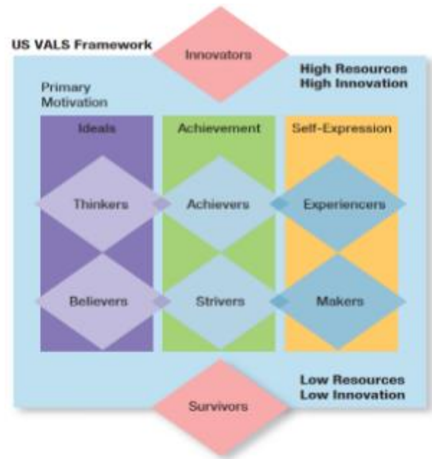


Figure 151: Vals framework

- Targeting: The process of evaluating each market segment's attractiveness and selecting one or more segments to enter. Making the right fit between the company and the specific customer. Process of choosing.
  - You can see this process from all kinds of perspectives.

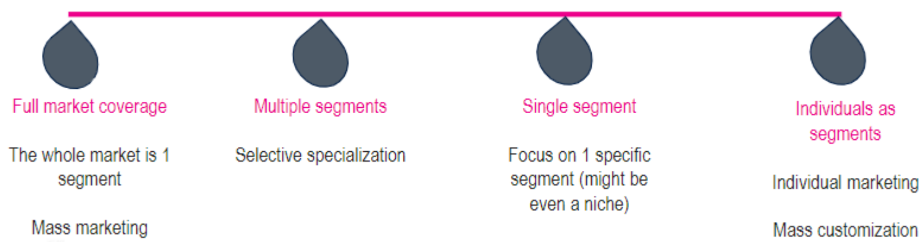


Figure 152: Perspectives of the targeting process

Lecture 4 – Product and positioning

Ethics

From the marketing perspective, marketing is not making people buy things they do not want. It is creating things that customers actually need. So, again, creating value. Marketing can however be used for the 'bad', so using tricks/manipulating people so they buy things (pushing products).

Wheel of ethics. Some questions to check whether your product adds value to the customer.

- To what extent does your design make customers happy?
- To what extent would your design be appreciated by every citizen of the world?
- To what extent does your design contribute to the relationship the organization has with its customers?
- To what extent does your design respect all possible human rights?
- To what extent does your design contribute to our planet and all the people living on it?
- To what extent would your design be appreciated by the person you admire most?

Knowledge clip 4a – Product strategy

The marketing mix consists of the 4Ps. This knowledge clip is all about the P of 'product'. How do you offer value to your customers? For product, this is through your product strategy.

Figure 153: The marketing mix

- Product: Anything that can be offered to a market to satisfy a want or need. Not just tangible.
- Product levels → Each level adds more customer value, and together the five constitute a customer value hierarchy.
  - Core benefit: The service or benefit the customer is really buying.
    - E.g. For a hotel → A night's sleep.
    - E.g. For a train → Going from A to B.
  - Basic product: The core benefit turns into a basic product.
    - E.g. For a hotel → Bed, bathroom, closet, etc.
    - E.g. For a train → The train (but for this core benefit could also be a bike or car).
  - Expected product: Attributes and conditions buyers normally expect.
    - E.g. For a hotel → Clean sheets, fresh towels, etc.
    - E.g. For a train → A place to sit, more or less clean, it works (going on time).
  - Augmented product: Exceeds customer expectations (competition).
    - E.g. For a hotel → Special service for kids, room service, etc.
    - E.g. For a train → Entertainment during traveling, nice designed train station.
  - Potential product: Possible augmentations and transformations.
    - E.g. For a hotel → Sleep vacation.
    - E.g. For a train → Self-driving bike, traveling by drone.

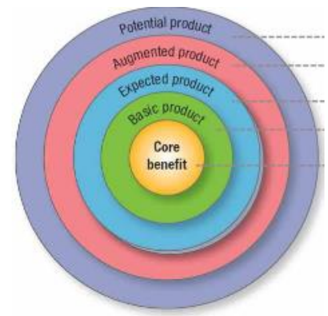


Figure 154: Product levels

- Product classifications. 3 types of classification.
  - Different products have different roles in people's lives, and they are sought after differently. In that sense, marketing actions must adapt accordingly.
  - A. Durability
    - Nondurable goods, durable goods, services.
  - B. Consumer goods
    - Convenience goods, shopping goods, specialty goods, and unsought goods.
  - C. Industrial goods
    - Materials and parts, capital items, supplies, and business services.
- Choosing a good position in the market is all about differentiation. How are you standing out?
  - Product differentiation
    - Form, quality, style, features, etc.
  - Service differentiation

- Ordering ease, returns, installation, etc.
  - Differentiation based on design
    - E.g. Alessi *(figure 34)* → Adding a specific emotion to your product. You add something extra to your product design, even though the product has the same function as another product.

Figure 155: Products from the brand Alessi

  - Differentiation based on environmental concerns.
    - E.g. having the lowest ecological footprint.

Figure 156: The product hierarchy

- A system perspective product hierarchy. *Figure 35* shows the product hierarchy using Listerine as an example.
- A system perspective on product systems.
  - E.g. offering a package deal of all the elements belonging to a product you are buying. → A cover for the phone you are buying.
- A system perspective on product mix (assortment) *(figure 24)*.
  - Width: How many product lines?
  - Length: Total # items in the mix.
  - Depth: How many variants?

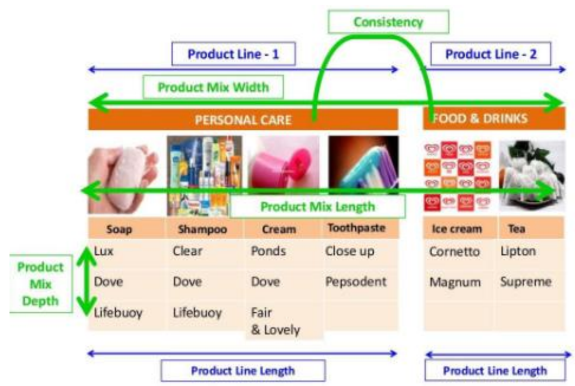


Figure 157: System perspective on the product mix.

Knowledge clip 4B – New product development

New product development is hard. Why many innovations fail…

- Endowment effect: People hold on to what they already know and have (people place more value on the products they own than on products they don't own).
- Loss aversion: People hate to lose and avoid risks (innovative products are risky).
  - With new products, you do not know jet if the product is going to be a loss or a gain.
- Change aversion: People don't like change, since change costs mental energy.
- Dilemma: You need innovation to stay ahead of the competition, but customers don't adopt innovations easily.

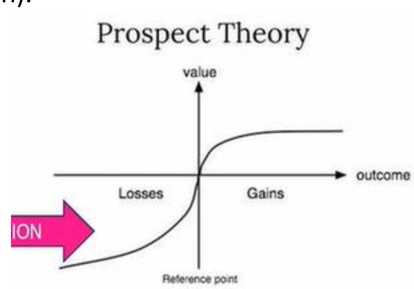


Figure 158: The prospect theory. A visualization of loss aversion.

Types of innovation

- Continuous innovation: Improvement of an existing product.
  - Less risk involved for the customer.
  - E.g. shampoo that is constantly changing its formula a bit.

- Dynamically continuous innovation: Modification of existing products that are affecting consumer behavior.
    - E.g. from a fixed computer to a portable laptop.
    - Small change for the product, large change for the consumer.
- Discontinuous innovation: Brand new product.
    - Can work really well or fail completely because people do not know what to do with this new product.
- Incremental innovation: A series of small improvements made to a company's existing products/services. These low-cost innovations help further differentiate a company from the competition.
    - Takes time for the consumer to adopt if they adopt the product at all.

Adoption of innovation. Whether an innovation is adopted is influenced by 2 things.

- The **relative advantage** that the new product is offering.
- The ease at which the new product is **fittable** in the life of the consumer.
- Maya principle (Loewy). This principle shows that there has to be some balance between the relative advantage and how fittable the product is.
    - **M**ost **A**dvanced **Y**et **A**cceptable

Design thinking for product development.

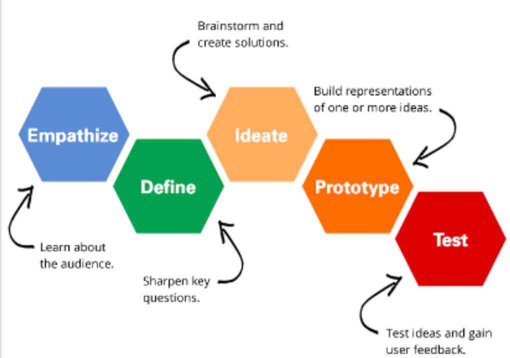


Figure 159: Product development phases

- Finding a balance between innovation and a customer perspective.
- The whole process of product development starts and ends with the user (customer).
    - First, the empathize phase: Really listening to the customer, understanding what the customer needs, what value he has, and how you can create value for the customer.
    - Based on the empathize phase you define a **design** challenge.
    - Then you go into the ideation phase, in which you brainstorm and create solutions for new products. You could do this phase with the customer.
    - Some ideas from the ideation phase turn into a **prototype**, which you **test** (with a customer).
        - Rapid prototyping: Designing products on a computer and producing rough models to show potential customers.

Knowledge clip 4C – From development to commercialization

The process from development to commercialization. When, where, and whom?

- When? First mover or later entrant?
- Where? Which market? International or local?

- To whom? Set the first target group. (the main topic of this knowledge clip) To see who is adopting when a new product (innovation) there is a curve.

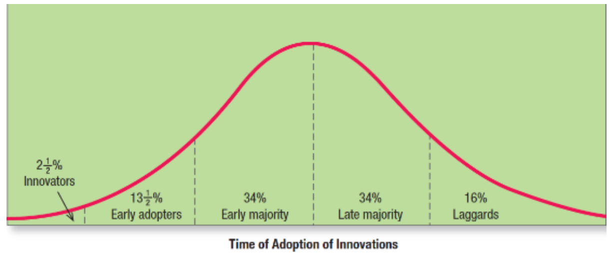


Figure 160: Which consumers adopt a new product when?

  - Innovators and early adopters. These groups are needed in the process of product development toward commercialization. These groups often consist of adolescents (18-25) because they have more dopamine (which creates thrill-seeking behavior). So, this is the group to target with new products because they are most open to new things and see the least risk.
    - If the innovated product is not fit for adolescents → Go for the high-dopamine novelty seekers and hope they serve as a bridge to the rest of the population, or go for the conservative masses, in which case the idea must be wrapped in a cloak of familiarity (communicate how easy the innovation fits into their life. Pretend that the innovation is not that innovative).
- <u>Mere exposure effect:</u> The more you get **exposed** to a specific new product, you get used to it and if you get exposed to it, even more, you might even love it. (This doesn't hold for every product.)

Knowledge clip 4D – Value proposition canvas

<u>The value proposition canvas:</u> A tool that will help you design, test, build, and manage great customer value propositions. It is all about making a fit between the design value and what you have observed from the customer. (Osterwalder)

- The tool is based on 2 elements of your business model. Customer segments whom you intend to create value for. And a value proposition that you believe will attract customers.
- Shows the fit between what you offer and what customers want.
- <u>Customer segment profile:</u> Describes the characteristics of your customers in more detail. These are the customer characteristics you can observe about your customer in the market. Composed of:
  - The jobs the customers are trying to get done in their work and their lives. Jobs describe important issues customers are trying to solve in their work or their lives. Tasks they try to perform and complete. Problems they are trying to solve. Or the needs they are trying to satisfy.
    - Jobs can have a functional, social, or emotional intent.
    - Some jobs are crucial to the customer, while others will be trivial.
  - The related pains outlining the negative aspects they hate or would like to avoid. Describes the pains annoying the customer before, during, and after getting a job done.
    - Some pains will be severe, and others will be light.
  - The gains describing the positive outcomes and benefits which your customers would love to have. The outcomes and benefits your customers require, expect, desire, or would be surprised by.
    - Some will be more relevant to the customers than others.

- <u>Value proposition map:</u> Describing the features of your value proposition that you are designing to address your customers' most important jobs, pains, and gains. Composed of:
  - Products & services your value proposition is built around.
    - Outline the bundle of products & services you are offering customers to help them get a functional, social, or emotional job done. And to address their pains and gains.
  - The pain relievers outlining how your products and services alleviate customer pains.
    - Make explicit how your products & services will alleviate specific customer pains before, while, and after the customer is trying to get a job done.
    - They show which of all your customer pains your value proposition is addressing, by eliminating or reducing them.
  - The gain creators describe the positive outcomes and benefits your products & services create for your customers.
    - Make explicit how your products & services create customer gains.
    - They show which of all the customer gains your value proposition is addressing, by creating benefits and outcomes.

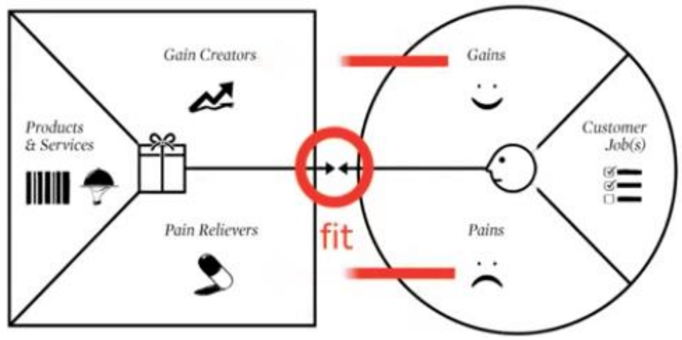


Figure 161: Outline of the value proposition canvas.

- With this customer segment profile and value proposition map, you have created a **solution fit** when the features of your value proposition map perfectly match the characteristics of your customer segment profile.
  - When the market validates this match, and your value proposition gets traction with real customers, you have achieved a so-called **product market fit**.

Lecture 5 – Price and place

The price should fit the setup → If you go to a discount store, you expect low prices. The price of the product has some communicative value. The prospect theory also holds for pricing. Consumers experience prices as a relative element, they use a reference point. This reference point can be anything:

Price	Fee	Fare	Rate
Toll	Premium	Honorarium	Special Assessement
Bribe	Dues	Salary	Commission
Wage	Tax	Tuitition	Rent

Figure 162: Different types of "prices".

- Typical price.
- "Fair price" (what consumers feel the product should cost).
- Last price paid.
- Upper-bound price (maximum most consumers would pay).
- Lower-bound price (minimum most consumers would pay).
- Historical competitor prices.
- Expected future price.
- Usual discounted price.

A higher price does not always cause price pain. Sometimes, it can actually be rewarding by giving the consumer a more "wow effect". *For example, an experiment was conducted with wine. People drank the same wine while thinking it was a different wine each time. People thought they were getting more expensive wine when it was actually the same. The "more expensive" wines were valued more by the tasters.*

The internet has changed the pricing strategy because now it is very easy to compare prices.

Anchoring effect

If you use a specific reference point as an anchor to set your value/guess. So, use a reference point as an anchor to set your judgment. (Kahneman & Tversky). *For example, if you ask people in a survey how much they are willing to pay for a product, they will use the number of the question they are answering as a reference point. So, if you ask the same question later on in the survey, people will fill in a higher price than when asked earlier.*

Knowledge clip 5A – Pricing

The pricing strategy. The 6-step process of setting the price.

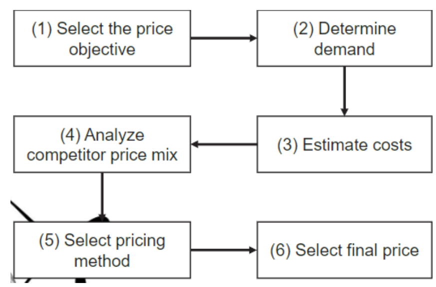


Figure 163: 6 step pricing strategy

1. Select the price objective: What are you trying to achieve with this price? Usually, companies have different price objectives in different stages of the product life cycle.
    a. Maximum current profit.
    b. Survival
        i. *For firms plagued with overcapacity, intense competition, or changing consumer desires.*
    c. Maximum market skimming (start high and then lower it) → Often used with electronic products.
        i. *E.g. A new version of a PlayStation is expensive. The older the product gets (the more new versions are developed) the cheaper it gets.*
    d. Market penetration → Particularly at the beginning of a product life cycle (second phase).
    e. Product-quality leadership.
2. Determine demand: Inelastic or elastic? *(figure 43)*
    a. Elastic demand: A small change in price causes a big change in quantity.
    b. Inelastic demand: A small change in price causes a small change in demand.

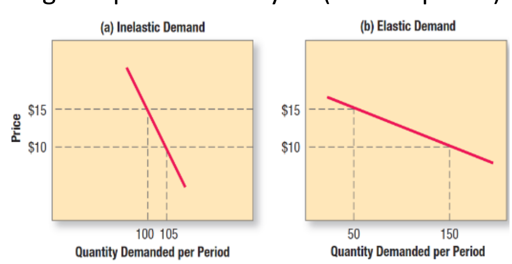


Figure 164: Inelastic vs. elastic demand

3. Estimate costs:
    a. Types of costs
        i. Fixed
        ii. Variable
        iii. Total and average (per unit)
4. Analyze competitor price mix. A firm must take competitors' costs, prices, and reactions into account.
    a. Consider substitutes
    b. High price might attract competitors

        c. Risk of price war

5. Select a pricing method. 3 perspectives.
    a. Cost-based pricing: First look at the costs. Based on these costs you set a price.

Figure 165: Cost-based pricing

        i. Markup pricing: Determine the average costs and add a profit margin. This combined is your price *(see figure 45)*.
            1. Also called **plus pricing.**
        ii. Targeted return pricing: Don't just look at the costs, but also the expected revenue. Subtracting this you get the (predicted) profit. Set the price so that the predicted profit is the profit you want.

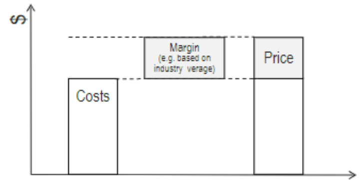


Figure 166: Markup pricing

    b. Value-based pricing: Set the price according to how the customer values the product.

Figure 167: Value-based pricing

    c. Competition-based pricing:
        i. Going-rate pricing: Pricing according to market prices. Often used when the pricing method is very difficult.
            1. Oligopolies (larger companies set the price). Smaller companies follow the leader.
        ii. Auction-type pricing (only for very specific markets).

6. Select final price: These aspects below are the boundaries to take into account.

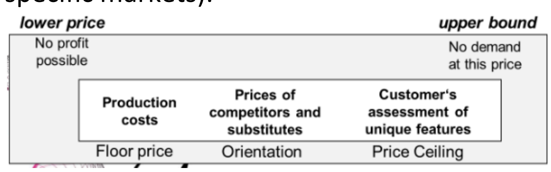


Figure 168: Boundaries of pricing

    a. Production cost defines the baseline, floor price.
    b. Substitutes and competition give an Orientation.
    c. Customer evaluation that defines the ceiling (price ceiling).
    d. Price adaptation strategies. When you have set a price, the price is not always fixed, you can still decide to adapt the price.
        i. Geographical pricing: Asking for different prices in different countries. Or taking into account shipping costs in the price.
        ii. Discounts/allowances: Promotions or sales.
        iii. Promotional pricing:
        iv. Differentiated pricing:
            1. Price discrimination: Asking for different prices from different consumers. For example, based on age.

Knowledge clip 5B – Marketing channels and delivering value

<u>Marketing channel:</u> Sets of interdependent organizations involved in the process of making a product or service available for use or consumption. This channel can be organized in all kinds of ways *(figure 48)*.

- <u>Direct channel:</u> From producer to consumer.
- <u>Retail channel:</u> Via a retailer.
- <u>Wholesale channel:</u> Via wholesaler/distributor, and retailer.
- <u>Agent channel:</u> Via agent/broker, wholesaler, and retailer.

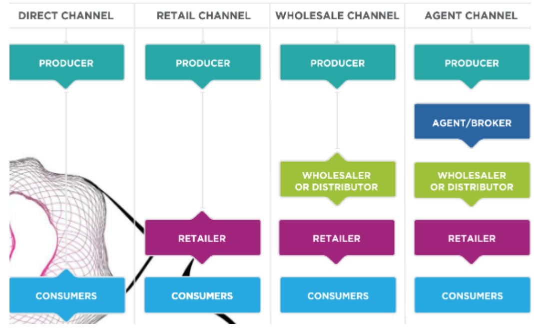


Figure 169: Different marketing channels

When designing a distribution strategy, you need to decide if you want to do it from a push or a pull perspective, or both.

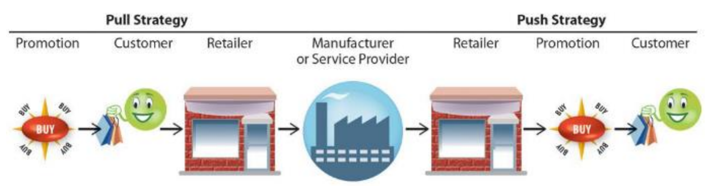


Figure 170: Push vs. pull strategy

- <u>Push strategy:</u> This is my product/service and I am trying to push it to the customer. This is about sending.
- <u>Pull strategy:</u> I am trying to pull the customer to my product/service. This is about attracting.
- <u>Both:</u> A combination of push and pull strategy.

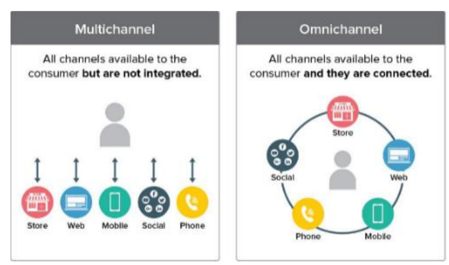


Figure 171: Multichannel vs. omnichannel

Multichannel vs. omnichannel market perspective.

- <u>Multichannel:</u> There are different channels that are side by side. So, they are not integrated, but separately offered to the customer.
  - A company is using >2 marketing channels to reach customer segments in one market area.
  - E.g. You can buy Lego at different selling places.
- <u>Omnichannel:</u> Multiple channels are aligned and connected to each other. More of a customer journey.

Figure 172: Omnichannel example

Digital channel revolution → Combining the best of both worlds. Digital and real-life stores.

- Customer support in-store/online/phone.
- Check online for product availability at local stores.
- Order products online to pick up at the store.
- Return a product purchased online to a nearby store.

Marketing channel flows

- Channel types
  - Sales
  - Delivery
  - Service
- Channel levels
  - Zero-level channel (same as direct channel)
  - One/two/three-level channel (intermediaries)
  - Reverse-flow channels (reuse, refurbish, recycle)

Channel strategy

- Channel selection (sales)
- Distribution intensity (delivery)
- Channel integration (service)

There are 4 steps to follow when designing a market channel strategy.

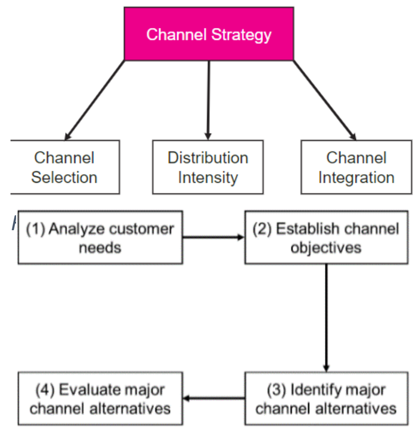


Figure 174: Steps for channel strategy

- Step 1: Analyze customer needs.
  - Lot size → How many at once?
  - Waiting/delivery time.
  - Spatial convenience → Easy geographical access.
  - Product variety.
  - Service backup.
- Step 2: Establish channel objectives.
  - Service output levels.
  - Consider the macro-environment (economy, social trends).
  - Positioning.
- Step 3: Identify major channel alternatives. You need to know the strengths and weaknesses of each channel.
  - Decide between channel trade-offs.
    - Types of intermediaries.
      - E.g. Audio system for the car industry, dealers, and audio experts.
    - Number of intermediaries.
    - Terms/responsibilities of channel members.
- Step 4: Evaluate major channel alternatives.
  - Find the best cost-benefit.
    - Different channels have different costs *(figure 54)* and generate different added value.
  - Understand risks:
    - Dilution, cannibalization
      - Marketers must be careful not to dilute their brands through inappropriate channels.

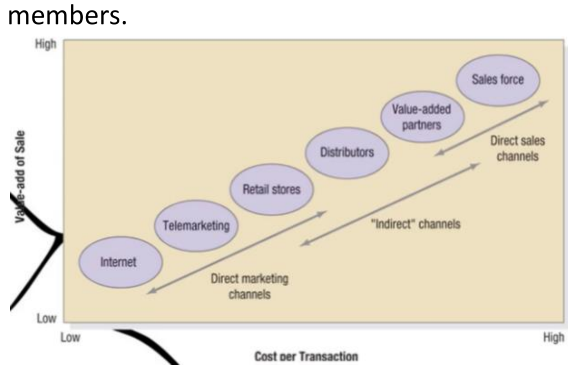


Figure 175: Different channels have different costs.

            - Legal and ethical issues
                - Suasive distributor
                    - *<u>Exclusive distribution:</u> Allows a firm to maintain control over service level and obtain more dedicated & knowledgeable selling.*
                - Territorial agreements
                - Tying agreements (forcing to buy the company's products).

Lecture 6 – Promotion

Marketing communications represent the voice of the company and its brands. It is trying to establish a dialogue with the customer. Promotion is communicating the product value through storytelling.

Knowledge clip 6A – The marketing communications mix

<u>Marketing communications:</u> How firms attempt to inform, persuade, and remind consumers, directly or indirectly, about the products and brands they sell.

- Storytelling
- Relationship building
- Value
- Thought leadership

<u>Marketing communications mix:</u> The toolbox consists of 8 elements used by the marketing communications manager. Every tool has its own characteristics.

- Advertising
    - Pervasiveness
    - Amplified expressiveness
    - Impersonality
- Events and experiences
    - Relevant
    - Involving
    - Implicit
- Mobile marketing
    - Timely
    - Influential
    - Pervasive
- <u>Sales promotion:</u> A marketing activity that is designed to increase sales, encourage customer loyalty or generate brand awareness.
    - Attention
    - Incentive
    - Invitation
        - *E.g. A trade show.*
- Personal selling
    - Customized
    - Relationship-oriented
    - Response-oriented
- Direct and database marketing

  - Personal
  - Proactive
  - Complementary
- Public relations and publicity
  - High credibility
  - Ability to catch buyers off guard
  - Dramatization
- Online and social media marketing
  - Rich
  - Interactive
  - Up to date

Advertising	Sales Promotion	Events and Experiences	Public Relations and Publicity	Online and Social Media Marketing	Mobile Marketing	Direct and Database Marketing	Personal Selling
Print and broadcast ads	Contests, games, sweepstakes, lotteries	Sports	Press kits	Web sites	Text messages	Catalogs	Sales presentations
Packaging–outer	Premiums and gifts	Entertainment	Speeches	E-mail	Online marketing	Mailings	Sales meetings
Packaging inserts	Sampling	Festivals	Seminars	Search ads	Social media marketing	Telemarketing	Incentive programs
Cinema	Fairs and trade shows	Arts	Annual reports	Display ads		Electronic shopping	Samples

Figure 176: Marketing communications mix example.

Digital revolution. Types of media, its advantages and disadvantages.

- Paid media (Facebook advertisement, search ads SEO).
- Earned Media (Facebook post, positive WOM).
- Owned media (Facebook page, website).
  - Advantages
    - Can offer or send tailored information/messages.
    - Can trace effects by UVs clicks on a page/ad.
    - Contextual placement.
    - Can place advertising based on search engine keywords.
  - Disadvantages
    - Consumers can screen out most messages.
    - Ads can be less effective than they appear (bogus clicks).
    - Lost control over online messages via hacking/vandalism.

Knowledge clip 6B – Effective marketing communication

Macro-model vs. micro-model.

- Macro-model: Describes the communication process. This process loop is generally how communication works.
    - For each communication someone is sending a message and coding the message. The receiver is decoding the message.
    - There may be some noise in the messages. E.g. words that someone doesn't know.
    - In general, the messages will create some kind of response.

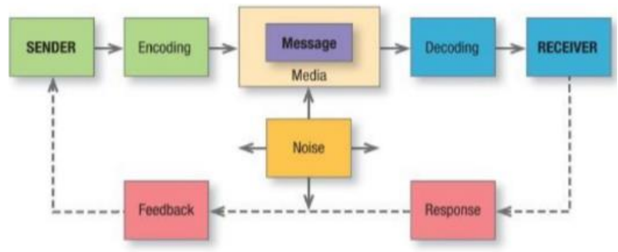


Figure 177: Macro model

- Micro-model: Focusses more on what happens in the individual (consumer). Consumer's specific responses to communications. There are different micro-models *(see figure 57).*

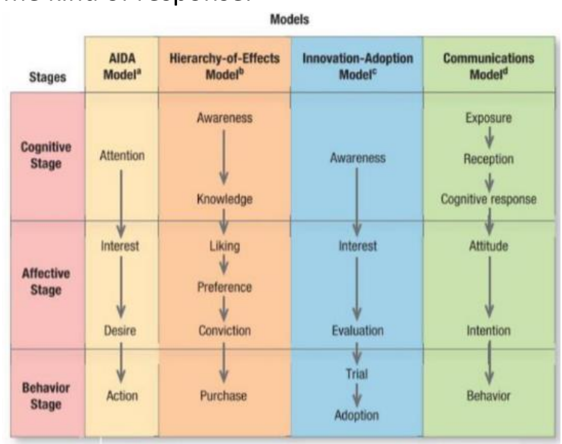


Figure 178: Micro model

The ideal campaign.

- The right consumer is exposed to the right message at the right time and place.
- It causes the consumer to pay attention.
- It correctly positions the brand in terms of points of difference and points of parity.
- It motivates consumers to consider the purchase of the brand.
- It creates a strong brand association.

Steps in developing effective communication

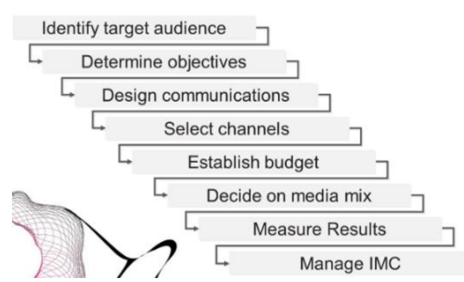


Figure 179: Developing effective communication steps.

- Identify the target audience.
- Determine objectives
    - Establish category needs.
    - Build brand awareness.
    - Build brand attitude.
    - Influence purchase intention.
- Design communications
    - Message strategy (what to say).
    - Creative strategy (how to say it).
    - Message source (who says it).
        - Information appeal: Elaborates on product or service attributes or benefits.
        - Transformation appeal: Elaborates on a nonproduct-related benefit or image > stir up emotions. It emphasizes the experience that consuming a good or service will provide rather than focusing directly on the features or benefits of the product itself.
            - *E.g. Pringle's slogan "Once you pop, the fun don't stop".*

- Select channels
    - Personal communications channel: Lets two or more persons communicate face to face or person to the audience through a phone, surface mail, or e-mail.
    - Non-personal (mass) channel: Communications directed to more than one person and include advertising, sales promotions, events & experiences, and public relations.
    - Integration of communication channels: The role of opinion leader.
- Establish budget
    - Affordable method
    - Percentage-of-sales method
    - Competitive-parity method: Using competitor advertising spending as a benchmark for a company's own spending.
    - Objective-and-task method
        - Establish market share goal.
        - Select % of the market reached by advertising.
        - Estimate % of prospects who should try the brand.
        - Calculate ad impressions per 1% trial rate.
        - Find gross rating points to be purchased.
        - Calculate the budget for the cost of a gross rating point.
- Decide on media mix
    - Marketing communications mix (see knowledge clip 6A for these elements).
- Measure results
- Manage IMC

Figure 180: Measure results and manage IMC.

Go rock your studies

GOOD LUCK!

Stress