InterValue
Inter-regional cooperation for valorisation of R&D

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New Product Development (NPD) Guide

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INTRODUCTION

Valorisation or exploitation of an R&D result is a process which is stimulated by the decision or expectation that an R&D result may attract the interest of a potential investor. In competitive terms an R&D unit is sustainable and viable when it produces “attractive” R&D results. Atraction might be illustrated by the interest for research collaboration, a spin-off company, or direct funding of the R&D unit. However attraction is not only stimulated by the scientific value of the research team but also from their capacity in presenting their R&D results in business terms. This capacity is built only when an R&D result mostly follows the stages of a new product. Notably the creation of a R&D result which is viable and attractive in business terms resembles the process of New Product Development.

It is obvious that when we are considering R&D results and not the products of a company, we should have a slightly different approach. However when we consider a market oriented research unit, there should be a sort of marketing approach since distribution of R&D results to the market is based on a constant communication with specific channels. Furthermore in the quite usual case where an R&D unit concentrates on its scientific role and its results are distributed by specific market collaborators (private companies), these business collaborators of the R&D units come across with specific business questions which should be in full consideration of the R&D units. Anyhow the R&D result in our discussion is a product to find its way to the market and market approach is anyhow a need in all its development stages.

In this stage of a new R&D result development, the R&D unit could consider alternatives about how this R&D result will approach the market, mainly as regards to the collaboration schemes. Alternative channels could be:

1. A predefined collaboration with a specific company. In this scheme there are dinstint roles in the process. The R&D unit stays in its scientific role but the company should have some prior knowledge on the product field and decisions about further market approach are taken by the R&D unit and the business collaborator together. In that case all stages until the market launch resemble to a typical New Product Development process. According to the expected range of the R&D result the product market launch is done by the business collaboraror brand name or the creation of a spin-off company is considered

2. An agreement with an investor (usually a venture capital). In such a scheme there is more responsibility given to the R&D unit but all stages have again a highly market oriented approach.

3. Finally an existing approach is where members of the R&D team are major shareholders of a company which distributes the R&D results, which obvisously presumes existence of adequate resources.

All these approaches have a clear market orientation and the process of transforming and R&D result into a market product is quite similar to a typical market New Product Development process.

To avoid development of an R&D result that will not attract any investment or collaboration interest and to minimize the costs of such a development a sort of NPD Roadmap can be used. Such a roadmap is a tool that can help R&D units to successfully develop new R&D results or upgrade

existing ones through a series of logical steps, starting from the process of idea generation and ending at the launch of the product into a market.

This process contains a series of activities called "Stages" Each Stage contains information and well-defined series of activities concerned with the particular Stage of the development. In the end of each stage the R&D unit must consider the stage findings and have a go / kill decision In the next chapters each Level is analysed further, and all relevant information or tools that can be used are presented.

Each Level is split up in sections that include **a definition of the problem** that the Level is asked to tackle, a **possible solution** to the problem and an **analysis of the tools** available to tackle the problem. Each tool is properly defined, the references, on-line resources, software sources and consultancies or organizations that can help to use the tool are given and case studies of where and how the toll has been used are presented in separate sections. All Assessments are designed to work interactively with a potential roadmap user. Also tools and templates developed are given for the same reason.

The roadmap presented can be used not only as an informative tool but also as a complete guide of a NPD process. The tools, best practices and other relevant material presented, explained and analysed further down in the report are in most cases given in the form of files linked to this document so that a reader can use them to perform his own NPD process. The true purpose and final scope of this report is to provide the means for the development of a complete on-line NPD roadmap. One should note that the roadmap itself would not be able to answer all the questions or tackle all the problems of such a process unless the final user enters information whenever this is required and based on analysis results move forward into the process.

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Stage 1: Idea Generation

Every new R&D result with a valorisation potential should start from an effective **idea generation** process. This process is more narrow and specific than idea generation for business New Product Development since that is more open and covers a wider range of fields based on its production capacity. For an R&D unit a potential R&D result should be based on its technology and/or scientific potential.
The idea generation process should be on - going, have a specific purpose, involve the whole of the team including its clients or scientific collaborators, use a variety of methods, have one person in charge and not evaluate the gathered ideas. During the idea generation - gathering process one should not criticize the ideas of others, should be freewheeling and generate as many ideas as possible. The management of ideas is also very important at this stage due to the large number of ideas to be selected and their diversity.

1.1 Idea generation Tools & Solutions

Generation of new ideas for R&D results may come from members of the team, research collaborators, professional investors and business collaborators since an R&D result typically meets a specific existing or new need or solve a specific problem. It is therefore necessary to have information gathering mechanisms for needs and preferences by those parties. Then when all data is collected a series of tools can help the unit to translate them into new product ideas.

Collection of needs and preferences can be done easily using questionnaires either from feedback by the valorisation process in any sort of way for a previous research product or through on-line questionnaires. The golden rule in either case is to ask the proper questions that can give a complete picture of needs.

Research collaborators, participants in scientific meetings or conferences or even market factors (traders, consultants, etc.) involved in areas where our result might enter (in case of R&D results in the form of product) can be sources of new product ideas. The way market factors are communicating with the customers can show aspects of customer needs that cannot be shown in any market research. Fairs, seminars, expos and shows that other R&D units or research intensive companies participate are a good place of obtaining new ideas for either completely new products or supplements of existing products or upgrades of existing products. These events are places that “competitor” creativity is at a full-scale show and new innovation techniques or new technologies can be observed. (See Competitive Intelligence)

The expression of needs or characteristics of new product ideas can be put into tools such as Conjoint Analysis (CA), so that needs or demands can be transformed into new product ideas and these ideas can be managed properly. Some of the tools used such as QFD can also be used in creation of product concepts from product ideas and come up with a final product plan.

Furthermore there are techniques or methodologies such as Brainstorming, Competitive Intelligence, Think Tanks, the Delphi process, the Kano maps and Triz which can be used to generate ideas or manage them with or without the use of data collected. We will present indictive methods for idea generation.

1.1.1 Conjoint Analysis

In the 1960s and 70s, organizations and academics were looking for a way to understand how people are taking decisions. They needed to know how people behaved during interviews. Did they say things on top of their mind or did they say what the interviewer wanted to hear? In their studies, academics, found that by looking at the ways people made decisions could predict which choices would be made between products and services. This is how Conjoint Analysis was born. The analysis produces market models for products and services, which enable companies to either improve existing products or find ideas for new ones.

To understand how the analysis works, one should describe products according to their attributes and features. For example a telephone device can be described by its weight, its appearance, its battery life in the case of cordless phones etc. The analysis takes these attributes or features and asks people to make a choice between same family products of different attributes. By asking for adequate number of attributes or features, the interviewer can work out a numerical representation of how valuable each attribute is to a customer.

Knowing the values of each attribute in respect to customer weight, one can compare one product to a competitor one and optimise attributes for a new one that the customer will embrace.

Developing a Conjoint Analysis involves the following steps:

1. Choose product attributes, for example, appearance, size or price.
2. Choose the values or options for each attribute. For example in the case of size one can choose the levels 5, 10, 15 and 20 cm. The more options one chooses for an attribute the more burden will be placed no the respondents.
3. Define products as a combination of attribute options. The set of combinations of attributes that will be used will be a subset of the possible set of products.
4. Choose the form in which the attributes and the options will be presented, for example, as a paragraph or as a picture.
5. Decide how the responses will be differentiated. For example responses can be split up depending on the preferences of the respondents or depending on other characteristics of the respondents such as age, location, etc.
6. Select the technique that will be used to analyse the data. There are different models that can be used such as the Part-Worth model, the Liner model or the Ideal-Point model. In either way special software written especially for conjoint analysis must be used to perform the statistics.

Source: QuickMBA, "Conjoint Analysis", On-line http://www.quickmba.com/marketing/research/conjoint/

1.1.1.1 Case Studies - Examples

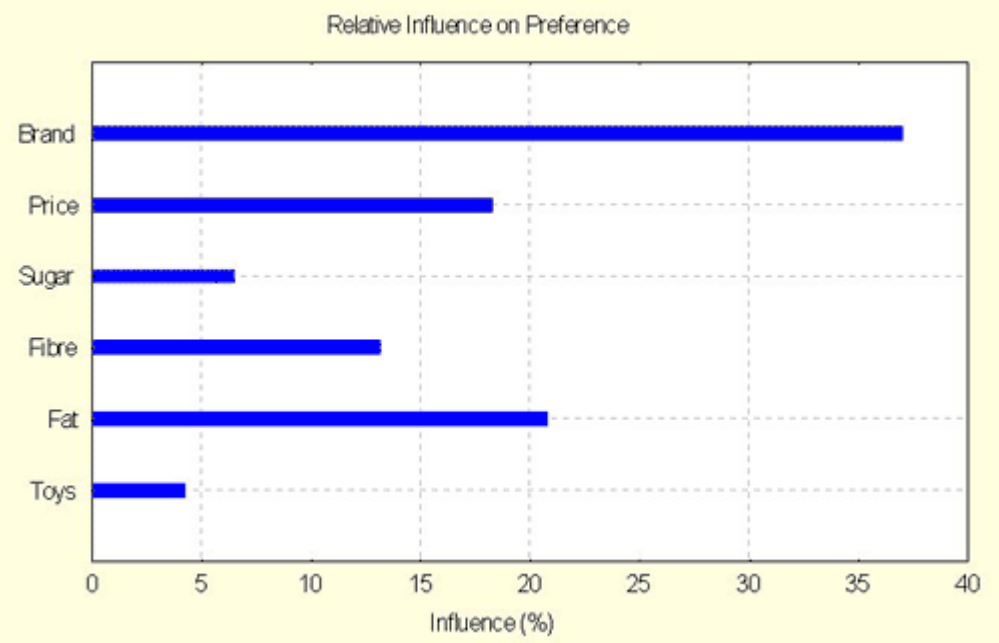
Conjoint Analysis Case Study: "Finding out which attribute of some of the breakfast cereals available in the market is more attractive to customers and therefore which attribute to optimize in a new cereal development"

The conjoint analysis study that focused on the problem described above was conducted by Sydney University in Australia, in behalf of a large food company that was considering entering into the

breakfast foods market. The study was conducted using 90 people, randomly selected as interview respondents. The product attributes and the levels of each product attribute used are given bellow.

ATTRIBUTES	LEVELS
1. Brand	Kellogg, Sanitarium, Uncle Toby's, No Frills
2. Price (relative to market average)	-30%, -10%, +10%, +30%
3. Sugar content	High. Low
4. Fibre content	High. Low
5. Fat content	High. Low
6. Toys inside the pack	Yes, No

Using some kind of software that was purchased from an outside source and written especially for conjoint analysis, the interview questions were designed based on the attributes and levels given above and the result data were analysed to yield the following graph of "Relative Influence on Attribute Preference".



Also three scenarios were evaluated using the same software and data. In the first scenario brand market share was evaluated when everything else were equal, in the second brand market share was evaluated considering the realistic prices of the four brands and finally in the third scenario the potential of a low fat product in the market was evaluated. The results of the analysis are given bellow.

SCENARIO 1: ALL EQUAL

	No Frills	Uncle Toby's	Kellogg	Sanitarium
Sugar	High	High	High	High
Fibre	Low	Low	Low	Low
Fat	High	High	High	High
Toys	No	No	No	No
Price(0%=avg)	0%	0%	0%	0%
Market Shr	4%	25%	62%	9%

SCENARIO 2: REALISTIC PRICES

	No Frills	Uncle Toby's	Kellogg	Sanitarium
Sugar	High	High	High	High
Fibre	Low	Low	Low	Low
Fat	High	High	High	High
Toys	No	No	No	No
Price(0%=avg)	-15%	-5%	+5%	-5%
Market Shr	8%	35%	49%	8%

SCENARIO 3: SANITARIOUM WITH LOW FAT

	No Frills	Uncle Toby's	Kellogg	Sanitarium
Sugar	High	High	High	High
Fibre	Low	Low	Low	Low
Fat	High	High	High	Low
Toys	No	No	No	No
Price(0%=avg)	-15%	-5%	+5%	-5%
Market Shr	2%	19%	31%	48%

Using the information above the food company was not only able to pin point the attributes i.e. the characteristics that customers considered important to a breakfast cereal and therefore focus its product development on them but also made an estimate of the market share that the company would gain or lose depending on the attribute(s) that the company would decide to work on during development.

1.1.1.2 Software Tools

http://www.surveyanalytics.com/conjoint/
Survey Analytics tool for Conjoint Analysis

http://www.sawtoothsoftware.com
Sawtooth Software Inc. provides a range of tools for conjoint analysis offered by Sawtooth Software Inc. There is a demo version, which includes the capability of writing web-based surveys for conjoint analysis. One can build his own questionnaire and analyse the survey using the local web server installed with the demo program.

http://www.palisade.com
The software offered by Palisade is called **@Risk** and it is really an add-on for MS Excel. It allows users to run probability distributions and Monte Carlo simulations for conjoint analysis data.

1.1.1.3 References

- Acito, Franklin and Arun K. Jain, "Evaluation of Conjoint Analysis Results: A Comparison of Methods", Journal of Marketing Research, 17, pages 106-112, 1980.

- Dobney, "Conjoint Analysis" **(http://www.dobney.com/Conjoint/Conjoint_analysis.htm)**, Dobney Corporation Limited, 2002
- Faura, Julio, "Contribution to Web-based Conjoint Analysis for Market Research," Management of Technology S. M. Thesis, Cambridge, MA: MIT, 2000.
- Mangen Research, "Introduction to Conjoint Analysis" **(http://www.mrainc.com/conj_intro.html)**, 2002
- SpeedBack Market Research, >"Conjoint Analysis" **(http://www.speedback.com/conjoint_analysis.htm)**, 2002

1.1.2 Morphological Charts

Morphological charts provide a well-structured approach to concept generation by widening the area of search for solutions to a defined design problem. It can help the design team to generate a complete set of alternative design solutions through a systematic analysis of the form, configuration or functionality of a product.

The chart is a visual way to capture the required product functionality and explore different ways and combinations to achieve that functionality. For each product function there may be a number of possible solutions. The chart enables these solutions to be expressed and provides the means for considering alternative combinations. This can help in the early visualization of the product architecture through the generation of different sub-solutions that no one has before thought about. When well used it can accommodate a user driven approach to product concept development.

The methodology behind the formation of such charts is simple. There are three main steps description of which is given bellow.

Step 1: List product functions or features that are needed to the product. The list should not be too long but should include the main product functions. Typically the list should not contain more than 10 items. It is useful to list the functions in an order of importance, putting the most important first and the least important last. Each function listed should be exclusive in regards to the others.

Step 2: List the potential solutions by which each function listed earlier can be achieved. One should think about new ideas as well as known solutions and all solution should be noted and expressed visually as well as using words. Any important characteristics of a solution should also be noted. Also a level of generality must be maintained.

Step 3: Draw up a chart containing all possible sub-solutions, which will represent the morphological chart. The chart will include the total solution for the product and will be made up from various sub-solutions. The total number of combinations can be large so the design team will need to select the ones that are feasible and producible. Also each solution or combination of solutions can be named so that it can be easily found and evaluated at a later time.

Source: Better Product Design, Institute of Manufacturing, University of Cambridge, On-line http://www.betterproductdesign.net/tools/concept/morph_charts.htm

1.1.2.1 Case Studies – Examples

Case Study: Mobile phone concept generation using a morphological chart.

For a widely used and available product as the one of a mobile phone, a morphological chart can be a very useful tool for finding a quick solution to new product concept generation. The possible functions of a mobile phone are easily recognized and include holding, storage, dialling, display, power supply, signal reception, signal processing, sound output, extra features, etc. Having these and more in mind one can easily find solutions. For example in the case of holding possible solutions can be stopwatch-type grip, attached to clothing, gun grip, etc. Inserting all the possible functions and their solution into a table as the one shown bellow forms a morphological chart from which a total solution for concept development can be generated.

Table 1: Morphlogical Chart Example for a Mobile Phone

Morphological chart for a mobile phone				
Function	Options			
Holding	Stopwatch style	Calculator style	not held	
Storage	Pin badge	on sleeve	on belt	in pocket
Entering no	Keypad	Voice	Bar code	
Display	LED	LCD	None	
Power supply	Mains	Battery	Solar	
Signal reception	Internal aerial	External aerial	Cable aerial	
Sound output	Speaker	Earphone		
Sound input	Internal microphone	External microphone		
Extra features	Calculator	Memory bank	Alarm	Games

Source: Better Product Design, On-line http://www.betterproductdesign.net/tools/concept/morph-charts.html

Considering the above morphological chart one possible solution could be a mobile phone that it is not held, can be stored as a pin badge, a keypad is used to dial the number, with no display, power by a battery, with an internal aerial, an internal microphone and with a large memory bank.

Source: Better Product Design, Institute of Manufacturing, University of Cambridge, On-line http://www.betterproductdesign.net/tools/concept/morph-charts.html

1.1.2.2 References

- "Morphological Charts" **(http://www.betterproductdesign.net/tools/concept/morph_charts.htm)**, Good Design Practice Program, Institute for Manufacturing & Engineering Design Center, University of Cambridge, UK, 2004
- Kardos G, "The Morphological Method" **(http://www.carleton.ca/~gkardos/88403/CREAT/MORPHO.html)** , Dept of Mechanical and Aerospace Engineering, Carleton University, Ottawa, Canada, 1998

1.1.3 TRIZ - Idea generation using a problem-solving tool

"Idea generation for product development is an inventive problem. Until some years ago its solution was centered into the field of psychology where the links between the brain and insight and innovation are studied. Methods such as brainstorming and trial-and-error were commonly suggested and used. Depending on the complexity of the problem, the number of trials would vary. If the solution lied within one's experience or field, such as mechanical engineering, than the number of trials were fewer. If the solution was not forthcoming, then the person that performed idea generation would look beyond his experience and knowledge to new fields such as chemistry or electronics. Then the number of trials would grow large depending on how well the person could master psychological tools like brainstorming, intuition, and creativity.

Genrich S. Altshuller, born in the former Soviet Union in 1926, developed a better approach, relying not on psychology but on technology. Serving in the Soviet Navy as a patent expert in the 1940s, his job was to help inventors apply for patents. He found, however, that often he was asked to assist in solving problems as well. His curiosity about problem solving led him to search for standard methods. What he found were the psychological tools that did not meet the rigors of inventing in the 20th century. At a minimum, Altshuller felt a theory of invention should satisfy the following conditions:

- Be a systematic, step-by-step procedure
- Be a guide through a broad solution space to direct to the ideal solution
- Be repeatable and reliable and not dependent on psychological tools
- Be able to access the body of inventive knowledge
- Be able to add to the body of inventive knowledge
- Be familiar enough to inventors by following the general approach to problem solving.

In the next few years, Altshuller screened over 200,000 patents looking for inventive problems and how they were solved. Of these (over 1,500,000 patents have now been screened), only 40,000 had somewhat inventive solutions; the rest were straightforward improvements. Altshuller more clearly defined an inventive problem as one in which the solution causes another problem to appear, such as increasing the strength of a metal plate causing its weight to get heavier. Usually, inventors must resort to a trade-off and compromise between the features and thus do not achieve an ideal solution. In his study of patents, Altshuller found that many described a solution that eliminated or resolved the contradiction and required no trade-off.

Altshuller categorized these patents in a novel way. Instead of classifying them by industry, such as automotive, aerospace, etc., he removed the subject matter to uncover the problem solving process. He found that often the same problems had been solved over and over again using one of only forty fundamental inventive principles. If only later inventors had knowledge of the work of earlier ones, solutions could have been discovered more quickly and efficiently.

In the 1960s and 1970s, he categorized the solutions into five levels.

- **Level one:** Routine design problems solved by methods well known within the specialty. No invention needed. About 32% of the solutions fell into this level.
- **Level two:** Minor improvements to an existing system, by methods known within the industry, usually with some compromise. About 45% of the solutions fell into this level.

- **Level three:** Fundamental improvement to an existing system, by methods known outside the industry. Contradictions resolved. About 18% of the solutions fell into this category.
- **Level four:** A new generation that uses a new principle to perform the primary functions of the system. Solution found more in science than in technology. About 4% of the solutions fell into this category.
- **Level five:** A rare scientific discovery or pioneering invention of essentially a new system. About 1% of the solutions fell into this category.

He also noted that with each succeeding level, the source of the solution required broader knowledge and more solutions to consider before an ideal one could be found.
What Altshuller tabulated was that over 90% of the problems engineers faced had been solved somewhere before. If engineers could follow a path to an ideal solution, starting with the lowest level, their personal knowledge and experience, and working their way to higher levels, most of the solutions could be derived from knowledge already present in the company, industry, or in another industry.
For example, a problem in using artificial diamonds for tool making is the existence of invisible fractures. Traditional diamond cutting methods often resulted in new fractures, which did not show up until the diamond was in use. What was needed was a way to split the diamond crystals along their natural fractures without causing additional damage. A method used in food canning to split green peppers and remove the seeds was used. In this process, peppers are placed in a hermetic chamber to which air pressure is increased to 8 atmospheres. The peppers shrink and fracture at the stem. Then the pressure is rapidly dropped causing the peppers to burst at the weakest point and the seedpod to be ejected. A similar technique applied to diamond cutting resulted in the crystals splitting along their natural fracture lines with no additional damage.
Altshuller distilled the problems, contradictions, and solutions in these patents into a theory of inventive problem solving which he named TRIZ. This theory can be applied to idea generation for product development or at the process of product development, as both are inventive processes."

Author: Glenn Mazur, Ideation International Inc., 23713 Riverside Drive, Southfield MI 48034 USA

Source: "Theory of Inventive Problem Solving", Ideation International Inc, On-line http://www.mazur.net/triz/

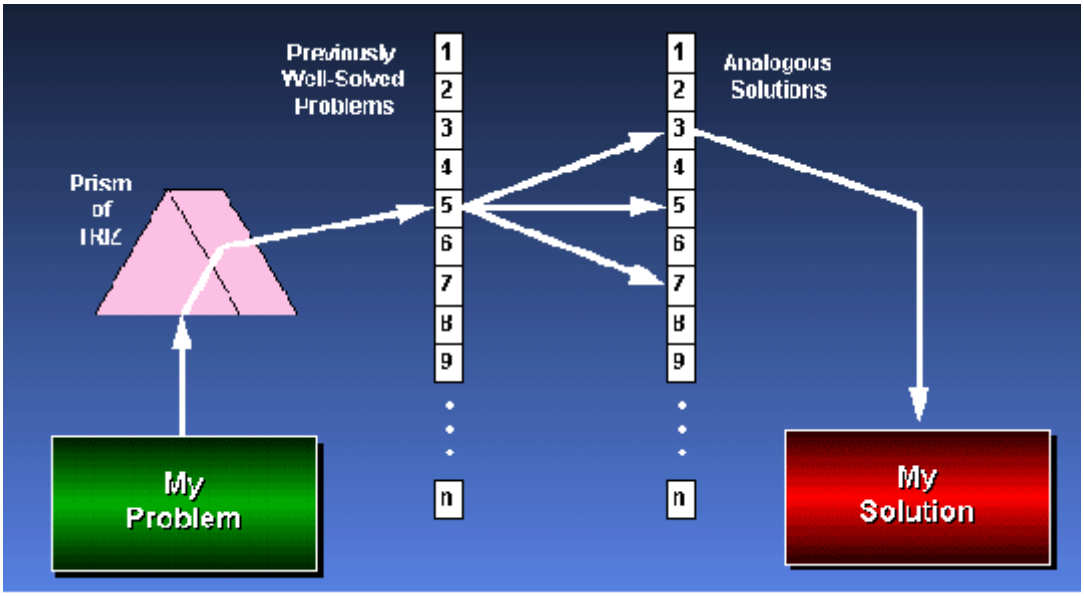
1.1.3.1 TRIZ Process Methodology

The TRIZ process as any process is governed by a simple and easy step-by-step methodology. This methodology is illustrated in the figure given below.

The main steps of the methodology are as follows.

Step 1: Identify the problem in hand. In the case of early product development that would be the generation of new product ideas according to already set criteria such as customer needs and desires. In later stages of product development the problem could be a technical, engineering or design issue that needs solving.

Figure 1: Graphical Representation of the TRIZ Methodology



Source: "Theory of Inventive Problem Solving", Ideation International Inc, On-line http://www.mazur.net/triz/

Step 2: Formulate the problem and create the prism of TRIZ. The problem is analyzed better and a full description of what is looked for is noted.

Step 3: Search for a previously solved problem. In the case of early product development this implies performing competitive analysis. Similar products that somewhat satisfy customer needs can be used as initiatives for new products by changing their characteristics or attributes to satisfy completely customer needs. In later stages of product development, a search in patent offices for example may reveal a solution to the problem in hand.

Step 4: Look out for similar solutions to the ones already found. Sometimes although a single solution may look to be the best by doing more research a new one could appear that would be even better one. One should carefully select the solution to the problem in hand carefully after serious consideration of all of the alternatives.

Source: "Theory of Inventive Problem Solving", Ideation International Inc, On-line http://www.mazur.net/triz/

1.1.3.2 Consultants - Experts

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- INSYTEC (TRIZ training programs) **(http://www.insytec.com/about.htm)**
- Elite Consulting **(http://www.elite-consulting.com/problem_solving.htm)**
- Triz Consulting Inc **(http://www.trizconsulting.com/)**

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Stage 2: Idea Screening

Once all viable ideas are gathered and managed, they must be further developed, examined, prioritised and evaluated so that a single product idea is selected for further development into a product concept. This whole process is called screening and is the main problem to solve in this Level using different tools and techniques.

2.1 Tools & Solutions

Idea screening should be done after definition of specific criteria with which we judge each idea such as:

- Alignment with Product Innovation Strategy
- Degree of compatibility with the R&D unit s values & principles (ex: moral, health, environmental)
- Market attractiveness / opportunity
- Project feasibility
- Degree of product advantage over other options
- Ability to leverage existing resources

From the book Launch It!: How to Turn Good Ideas Into Great Products That Sell (by Molly Miller-Davidson et al.) the authors give in the first chapters some great questions to ask when evaluating your own ideas. A number of “No”s should indicate the idea needs some work or should be scrapped. Here are the questions (in my own words):
Does the product represent something completely new and different from anything out there in the marketplace? Would it likely appeal to a specialty/niche segment of people?
Does the idea have a unique design to it, that’ll make it appeal to more people than a comparable product does now?
Will this idea offer a noticeably superior quality in comparison to competitive offerings? If so, can it remain in the same price range as those competitive products?
If it’s a popular item (in terms of category volume), would you be able to noticeably lower its price without affecting its quality?
Is the idea able to offer enough new features to differentiate it from the competition? If so, to what degree would these additional features be of value or seen as advantageous?
For popular products, will your idea enable you to produce and distribute it faster than the competition? Importantly, will this matter? Popular competitive products may carry a strong brand appeal which may be too high a hurdle. However, if the product category is a bit more commoditized, then speed to market will definitely be a strong advantage.
How much longevity does your product idea have? Is it part of an established category of products, a trend, or a fad? Having a grip on this is crucial. I’m not saying some product categories are no-growth, sometimes it depends on the sales channel. But obviously you don’t want to base a lot of business on a me-too product whose lifespan may only last a few years.

1. Similar to #7, how new is this idea compared to existing products in your portfolio or pipeline? Buyers are likely to be approached next season by similar products with the

additional features and attributes you'll be pitching. If you're redesigning a SKU to extend its lifespan, that may be fine. But ultimately, you should try and have additional, newer concepts in your development pipeline.

2.1.1 FMEA (Failure Modes and Effects Analysis)

Nowadays customers are placing increased demands on companies for cheap high quality and reliable products. As products become more and more complex, quality and reliability is getting very hard to be maintained by manufacturers. In previous years reliability and quality was achieved through extensive testing at the end of the product development process. The challenge was to design reliable and quality products from the beginning of product development and in particular at the early stages of product idea selection and product concept development.

FMEA (Failure Modes and Effects Analysis), is used by many companies as their central pillar of their design process, since it addresses in a big way the challenge mentioned above. FMEA can provide a structured approach to the analysis of route causes of product failure, the estimation of the severity of impact to the product, and the effectiveness of strategies for prevention. The output of the analysis is the generation of action plans to prevent, detect or reduce the impact of potential modes of product failure. When this analysis is conducted in the second Level of NPD i.e. the idea screening - product concept development, for each generated idea, the selection of the best idea that can result in a reliable and quality product can be achieved.

FMEA was firstly developed by the US military in the 1940's as a tool to improve the reliability of military equipment. It was quickly adopted by the aerospace industry and the automotive industry in the 70's. The analysis can be applied to address several issues such as organizational issues, strategy issues, product design issues, production processes and individual product components.

FMEA cannot only be used in the early stages of product development. During the design and product development processes updates are made to the product and its components. These changes can introduce new failure modes and it is therefore critical to review some or all of the FMEA analysis results by conducting an update to the analysis data.

Source: America Society for Quality, FMEA, On-line http://www.asq.org/learn-about-quality/process-analysis-tools/overview/fmea.html

2.1.2.1 References

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2.1.2 PMI Analysis

PMI (Plus / Minus / Implications) analysis is an improvement of the weighting the pros and cons technique. When one has selected a course of action, PMI is a good method of evaluating this course. The method can be used in any case when decision-making plays a great role in the success of a project. In the case of NPD it can be used in any Level but can be extremely helpful during Level 2 where screening and evaluating new product ideas take place and a decision for the best one must be made.

For the technique to be used a table is drawn having three columns headed Plus, Minus and Implications. Within the table all the positive and negative points for following a given course of action are written. Also their implications and outcomes are noted. If the decision is not obvious then one can score the table and sum up the scores to see whether implementing the decision and taking the given course of action is worth the effort.

A simple example - case study of the PMI analysis is given.

Source: Mind Tools, "PMI – Weighting the Pros and Cons of a Decision", On-line http://www.mindtools.com/pages/article/newTED_05.htm

2.1.2.1 Case Studies - Examples

A young professional is deciding where to live. Her question is "should she move to the big city"?

She draws up the PMI table below:

Table 1: PMI Example Table

Plus	**Minus**	**Implications**
More going on (+5)	Have to sell house (-6)	Easier to find new job? (+1)
Easier to see friends (+5)	More pollution (-3)	Meet more people? (+2)
Easier to get places (+3)	Less space (-3)	More difficult to get own work done? (-4)
	No countryside (-2)	
	More difficult to get to work? (-4)	
+13	**-18**	**-1**

Source: Mind Tools, "PMI – Weighting the Pros and Cons of a Decision", On-line http://www.mindtools.com/pages/article/newTED_05.htm

She scores the table as 13 (Plus) - 18 (Minus) - 1 (Implications) = - 6

For her, the comforts of a settled rural existence outweigh the call of the 'bright lights' - it would be much better for her to live outside the city, but close enough to travel in if necessary.

Source: Mind Tools, "PMI – Weighting the Pros and Cons of a Decision", On-line http://www.mindtools.com/pages/article/newTED_05.htm

2.1.3 SWOT Analysis

SWOT Analysis is a very effective way of identifying one's Strengths and Weaknesses, and of examining the Opportunities and Threats one can face. Carrying out an analysis using the SWOT framework can help focusing activities into areas where the company is strong, and where the greatest opportunities lie. By Performing a SWOT analysis, one can use the analysis results to screen new product ideas against the characteristics of one's company and ultimately its strategic goals.

The simplest way to carry out a SWOT Analysis one must write down answers to the following questions. Where appropriate, one must use similar questions:

Strengths:

- What are your advantages?
- What do you do well?
- What do other people see as your strengths?

One must consider this from his own point of view and from the point of view of the people he deals with. One mustn't be modest - be realistic. If there are any difficulties with doing this, one must try writing down a list of the company's characteristics. Some of these will hopefully be strengths!

Weaknesses:

- What could you improve?
- What do you do badly?
- What should you avoid?

Again, one must consider this from an internal and external basis - do other people seem to perceive weaknesses that you do not see? Are the competitors doing any better than the company? It is best to be realistic now, and face any unpleasant truths as soon as possible.

Opportunities:

- Where are the good opportunities facing you?
- What are the interesting trends you are aware of?
- Useful opportunities can come from such things as:
- Changes in technology and markets on both a broad and narrow scale
- Changes in government policy related to your field
- Changes in social patterns, population profiles, lifestyle changes, etc.

- Local Events

Threats:

- What obstacles do you face?
- What is your competition doing?
- Are the required specifications for your job, products or services changing?
- Is changing technology threatening your position?
- Do you have bad debt or cash-flow problems?

Carrying out this analysis will often be illuminating - both in terms of pointing out what needs to be done, and in putting problems into perspective. One can also apply SWOT analysis to one's competitors - this may produce some interesting insights!

Source: Manktelow James, "SWOT Analysis: Discover New Opoortunities. Manage and Eliminate Risks", Mind Tools, On-line: http://www.mindtools.com/pages/article/newTMC_05.htm

2.1.4.1 Case Studies - Examples

Case Study: "SWOT Analysis on a starting up small consulting business"

A start-up small consultancy business might carry out the following SWOT analysis:

Strengths:

- We are able to respond very quickly as we have no red tape, no need for higher management approval, etc.
- We are able to give really good customer care, as the current small amount of work means we have plenty of time to devote to customers
- Our lead consultant has strong reputation within the market
- We can change direction quickly if we find that our marketing is not working
- We have small overheads; so can offer good value to customers

Weaknesses:

- Our company has no market presence or reputation
- We have a small staff with a shallow skills base in many areas
- We are vulnerable to vital staff being sick, leaving, etc.
- Our cash flow will be unreliable in the early stages

Opportunities:

- Our business sector is expanding, with many future opportunities for success
- Our local council wants to encourage local businesses with work where possible
- Our competitors may be slow to adopt new technologies

Threats:

- Will developments in technology change this market beyond our ability to adapt?
- A small change in focus of a large competitor might wipe out any market position we achieve
- The consultancy might therefore decide to specialise in rapid response, good value services to local businesses. Marketing would be in selected local publications, to get the greatest possible market presence for a set advertising budget. The consultancy should keep up-to-date with changes in technology where possible.

Source: Manktelow James, "SWOT Analysis: Discover New Opoortunities. Manage and Eliminate Risks", Mind Tools, On-line: http://www.mindtools.com/pages/article/newTMC_05.htm

2.1.4.2 Tools and References

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NPD Stage 3: Business Analysis

Since the company has a great idea for a new product chosen, we need to check whether the finances are there to back up such a project. The business analysis level looks more deeply into the cash flow the product could generate, what the cost will be, how much market shares the product may achieve and the expected life of the product. So in this Level the business situation surrounding a proposed project is checked.

3.1 Tools & Solutions

The evaluation of the necessary financial resources for development of a concept into a new product can be done using specific tools such as "Cost - Benefit Analysis" for the calculation of expected costs and return of investment, "Gannt Charts" for the scheduling of the whole project from now until product launch, "Critical Path Analysis & PERT" for the management and relocation of resources if necessary and "Stakeholder Analysis" for the evaluation of support from the companies executives, the investors and all the people that can influence the NPD project.
Also in this Level the new product life cycle must be evaluated since this factor will greatly affect all above factors of the business analysis.

3.1.1 Cost Benefit Analysis

One of the tools available to select an idea for further development is Cost Benefit Analysis. Cost benefit analysis is a process which involves, whether explicitly or implicitly, weighing the total expected costs against the total expected benefits of one or more actions in order to choose the best or most profitable option. The formal process is often referred to as either CBA (Cost-Benefit Analysis) or BCA (Benefit-Cost Analysis).
Benefits and costs are often expressed in money terms, and are adjusted for the time value of money, so that all flows of benefits and flows of project costs over time (which tend to occur at different points in time) are expressed on a common basis in terms of their “present value.” Closely related, but slightly different, formal techniques include cost-effectiveness analysis, economic impact analysis, fiscal impact analysis and Social Return on Investment (SROI) analysis. The latter builds upon the logic of cost-benefit analysis, but differs in that it is explicitly designed to inform the practical decision-making of enterprise managers and investors focused on optimizing their social and environmental impacts.

Cost Benefit Analysis Tool of URENIO Research Unit

A Cost Benefit Analysis tool has been developed by URENIO Research Unit and can be found in http://www.urenio.org/e-tools/en/cost_benefit/index.html

3.1.2 Gantt Charts

Gantt Charts are used to analyze and plan complex projects. Specifically they can be used to plan the tasks ahead, to schedule all the tasks, to allocate resources and work out the critical path of a

project in terms of its required completion date. In this way Gantt Charts can be used to monitor the progress of a project. All activities sequential or parallel can be at any time checked and remedy actions can be taken if a project or a specific activity has fallen behind.

The most common software tool that is used by managers to build and manage Gantt Charts is Microsoft Project. The steps that are needed for the Gantt Chart to be built are the following.

- Listing all the project activities or tasks and their duration.
- Plotting the tasks onto a graph paper.
- Scheduling all the activities.
- Presenting the analysis.

A case study of the creation of a Gantt Chart for the development of a custom written computer project is available.

Source: "Gannt Charts: Planning and Scheduling More Complex Projects", Mind Tools, On-line http://www.mindtools.com/pages/article/newPPM_03.htm

3.1.2.1 Case Studies - Examples

Case Study: "Planning a custom written computer project".

Step 1: All the required tasks or activities are noted. Information of their duration, potential beginning and whether they are parallel or sequential is noted as well.

Table 1: Activities List

TASK	START	LENGTH	TYPE	DEPENDS ON
1. High level analysis	Week 1	5 days	Sequential	
2. Selection of hardware	Week 1	1 day	Sequential	1
3. Installation of hardware	Week 3	2 weeks	Parallel	2
4. Analysis of core modules	Week 1	2 weeks	Sequential	1
5. Analysis of supporting modules	Week 1	2 weeks	Sequential	4
6. Programming of core modules	Week 4	3 weeks	Sequential	4
7. Programming of supporting modules	Week 4	3 weeks	Sequential	5
8. Quality assurance of core modules	Week 5	1 week	Sequential	6
9. Quality assurance of supporting modules	Week 5	1 week	Sequential	7
10. Core module training	Week 7	1 day	Parallel	6
11. Development of accounting reporting	Week 6	1 week	Parallel	5
12. Development of management reporting	Week 6	1 week	Parallel	5
13. Development of management analysis	Week 6	2 weeks	Sequential	5
14. Detailed training	Week 7	1 week	Sequential	1-13
15. Documentation	Week 4	2 weeks	Parallel	13

Source: Mind Tools, "Gantt Charts – Planning and Scheduling More Complex Projects", On-line http://www.mindtools.com/pages/article/newPPM_03.htm

Step 2: The tasks are plotted onto graph paper. This will produce an untidy diagram as the one shown bellow.

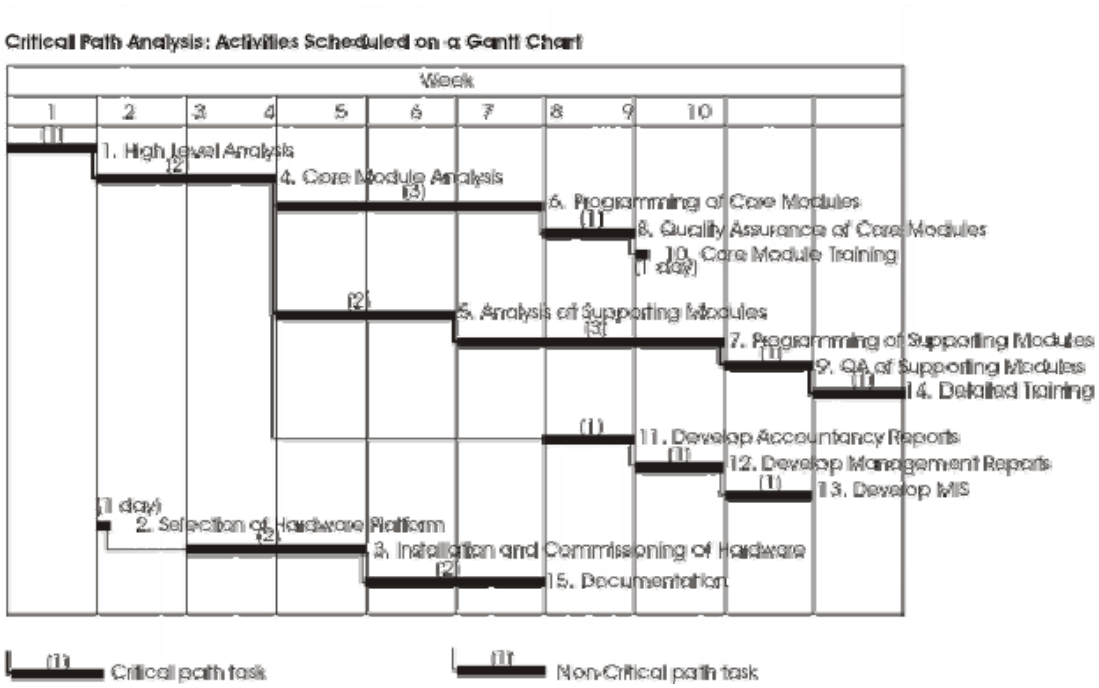
Figure 1: Plotting the Tasks

Source: Mind Tools, "Gantt Charts – Planning and Scheduling More Complex Projects", On-line http://www.mindtools.com/pages/article/newPPM_03.htm

Step 3: All activities are scheduled in such a way that the sequential activities are carried out in the required sequence. Parallel tasks are scheduled in such a way that they do not interfere with sequential ones.

Step 4: The analysis is presented. This can look something like the chart shown bellow.

Figure 2: Analysis Presentation



Source: Mind Tools, “Gantt Charts – Planning and Scheduling More Complex Projects”, On-line http://www.mindtools.com/pages/article/newPPM_03.htm

4.1.3.2 References

- Gannt Project tool, http://www.ganttproject.biz/
- Matthies L H, "Using the Gannt Chart to Plan and Control a Project", Systemation Inc, 1974.

4.1.4 Critical Path Analysis & PERT

Critical Path Analysis and PERT charts are two very powerful tools that can help a unit or a person to schedule and manage large complex projects. Both tools were developed in the 50's to manage large defense projects and are used ever since. Critical Path Analysis is similar to Gantt charts. It can help schedule large complex projects in a way that is familiar to Gantt Charts. The benefit of using Critical Path Analysis instead of Gantt Charts is that CPA can identify the reason behind the delay of a task or activity and very easily relocate resources so that the task can catch up and be completed on time. Also CPA allows the user to know the minimum time required for a task to be completed. This is very handy in the case of accelerated projects since CPA can identify which tasks can be moved along faster. The main disadvantage of CPA is that the relation of tasks is not so apparent as with Gantt Charts.

PERT (Program Evaluation and Review Technique) Chart is a variation of CPA. PERT Charts tend to have a more sceptical approach than CPA in terms of scheduling tasks. For the tool to be used, an estimation of the shortest possible time each task will take, the most likely length of time each task will take and the longest time each time will take must be taken into account. A formula is then used to calculate the time to use for each task. This is given bellow.

$$\text{Task time} = (\text{Shortest time} + 4 \times \text{Likely time} + \text{Longest time}) / 6$$

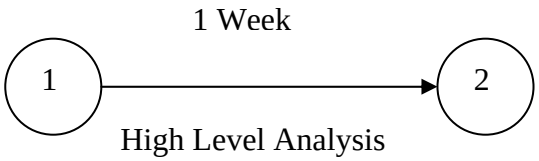
This is very helpful for getting realistic estimates of time.

Both tools can be used in a series of steps that are described bellow.

Step 1: All the activities of a project are noted along with their respective duration, starting point, type and dependency as with Gantt Charts.

Step 2: The activities are plotted as a circle and arrow diagram. For example a very simple diagram for the case study presented for Gantt Charts is shown bellow.

Figure 1: Simple Circle and Arrow Diagram



Source: Mind Tools, "Critical Path Analysis & PERT Charts", On-line: http://www.mindtools.com/critpath.html

Step 3: All the activities sequential or parallel are interconnected using arrows. And the complete CPA Chart is formed.

Step 4: Using the CPA Chart the steps or activities, which are required so that a goal is achieved, are identified.

Source: Mind Tools, "Critical Path Analysis & PERT Charts", On-line: http://www.mindtools.com/critpath.html

Stage 4: Testing

Product testing can occur in all levels of the NPD process. It can take the form of concept testing at the end of concept development, of prototype and beta testing at the end of the prototype development or of final product testing at the end of the technical implementation.

Regardless of the level or phase of the NPD process, the product testing process consists of three components: the creation of a testing strategy (which often includes the creation of test cases), the creation of a test plan (which includes test cases and test procedures and the execution of the tests.

The test strategy is a formal description of how a product will be tested. For the creation of such a strategy the testing team must analyze all the product requirements, write the test strategy and review the plan. The test plan may include test cases, conditions, the test environment, a list of related tasks, pass / fail criteria and some kind of risk assessment.

The test plan is prepared by reviewing all the functional requirements of the product. These requirements can be easily broken down into specific test procedures. The test procedures can define the test conditions, data to be used for testing and the expected results. The test plan should include tests cases or scenarios, which should be designed to represent typical and extreme situations that may occur during the product's life.

Tests execution is completed, by following the test documents in a methodical manner. Test documents are the results of the test strategy creation and the test plan development. As each test is executed a record of the test result must be kept in a test execution log. All test results noted in the execution log must be evaluated by engineers and screened against the pass / fail criteria set in the test plan. Any faults or bugs in the operation of the product should be fixed before the product goes through the technical implementation and manufacturing phase. There are cases where faults are not fixed since they are noted as low importance in the risk assessment prepared in earlier levels of development. After all tests are completed a summary is prepared and delivered to the project manager, the quality assurance manager and the leader of the test team. When all tests in the test summary are certified then the product takes the go ahead to the next level of development.

4.1 Tools & Solutions

The solution or solutions that deal with beta and market product testing vary and cover a lot of different aspects and issues. One should look into product development testing and the tests that must be carried out during this stage, he must give extra notice into major market research issues and he must know what kind of tests are available. Also some basic or in some cases specialized knowledge of prototyping techniques and testing must be in hand.

All the above are discussed in this Level as tools or methods or techniques and the Level aims to give a spherical informative point of view of what is available and what can be done to solve the problem of testing. Apart from that, the most important testing techniques are given bellow.

Unit testing. Unit testing occurs when all product components are tested and the expected test results are met or their differences are explained and accepted. It involves the testing of the product as a whole.

Functional testing. It is a black-box testing procedure designed to examine the functionality of the product. It is performed by specialized test engineers.

Usability testing. During this test the user-friendliness of the product is examined. This product characteristic is purely subjective and depends on the targeted product end-user or consumer. User interviews, surveys, market research results and other techniques can be used to define and analyze the test procedure and the test results.

Integration testing. Integration testing is the continuous testing of an application as new functionality is recommended. Programmers, engineers and testing personnel usually perform this type of testing.

System testing. System testing is a black box testing performed by the test team as the complete product is configured in a controlled environment. The purpose of the system testing is the validation of the products or application accuracy, its ability to perform all the tasks designed for and the simulation of real life scenarios.

End-to-End testing. This kind of testing is very similar to system testing since during the test situations that mimic real life are used. During this test the product or service or application is put to interact with other components that it will usually be connected to or incorporated with in real life.

Performance testing. This kind of testing verifies possible loads, volumes and response times that the product may be specified to have.

Installation testing. This test examines the way a new product or service can be installed, uninstalled, upgraded or changed.

Alpha testing. This test takes place when development is near completion. End-users or customers usually perform it and its results can only be used for minor design changes to be made.

Beta testing. As with alpha testing this test is performed by end-users or customers. The test is performed when all development is completed and just before the product or service is launched into a market.

Source: Better Product Design, Institute of Manufacturing, University of Cambridge, On-line http://www.betterproductdesign.net/tools/concept/testing.html

4.1.1 Rapid Prototyping

Rapid Prototyping (RP) is widely used in many industries such as aerospace, medical and consumer products industries and as the name suggests its use is to quickly make prototypes for communication and testing purposes. RP really refers to a set of technologies that can automatically construct models from CAD data. These models allow developers and R&D teams to quickly make three-dimensional designs of developing products. These models are used to simplify complex products and can lead to early tooling for manufacturing or production and early packaging planning. In this way substantial amounts of time and money are saved since manufacture, production and preparation of product launch can be developed before the product reaches its final

form. In addition RP models can do a few things that usual metal or plastic prototypes cannot. Simulations on the performance of the product can be run using the RP model and the CAD data.

A very important feature of Rapid Prototyping is Rapid Tooling (RT). RT is the automatic fabrication of production quality machine tools. Tooling for the production of new products is one of the most expensive steps in a manufacturing process since high quality is required. Tools often have complex geometries with dimensions of extremely low tolerances. Also they must be hard, wear - resistant and have extremely smooth surfaces. To meet these requirements tool mold construction can be very expensive and time consuming. So RP techniques are used to speed up the process. It is said that RP techniques can reduce tooling costs and subsequently product developing times up to 75%. Rapid tooling can be divided into two main categories: Direct and Indirect RT.

- **Direct Rapid Tooling** is when CAD data are used to construct models of tools in the same way as they it happens in the case of Rapid Prototyping for products. This technique is today in the development process.
- **Indirect Rapid Tooling** is when RP parts are used to construct molds and dies that are used to construct the tools.

A usual result of Rapid Prototyping is Rapid Manufacturing (RM). RM is the automated production of products direct from CAD data. Today only a small amount of products are produced in this way. As new materials and technologies become available, the RM technique will become more and more used.

RM can be expensive compared to traditional manufacturing processes especially compared with large mass production runs. For short runs, however, RM can be cheaper since it does not require tooling. RM is also the best technique for producing custom parts or products, which are tailored to the customer's specifications. Finally RM can be used when the product geometry is too complex, or contains internal voids and layered structures.

4.1.1.1 Prototyping Testing

When prototypes are ready, they must go through vigorous tests, which are divided into Functional Tests, Customer Tests and Market Tests. Functional tests are divided into two sequential types of tests: Alpha testing and Beta Testing. A brief description of each is given bellow.

- **Alpha Testing** means testing the product prototype within the company to see how it performs in different applications. Engineers or scientists do this usually within the R&D department and if all tests are successful the product prototype moves into Beta Testing.
- **Beta testing**, is a set of tests that are carried out using potential customers. These customers test the product prototype and provide feedback to the company of their experience using the product. The marketing department of a company usually supervises beta testing, although the results go back to the R&D department for possible refinements of the product prototype. It is most successful if the potential customers used are heterogeneous, if the potential application(s) is not fully known, if several decision makers, such as high executives or managers, are involved in purchasing the product and if the opinion leadership of early adopters is sought.

Customer Testing can take a variety of forms. One can bring customers into a lab and encourage them to test the prototype or giving them samples of the product prototype to take back into their

homes and test it. In home placement are common for products ranging from ice cream flavours to home appliances. For example when "DuPont" developed its new synthetic carpeting, it installed free carpeting into several homes in exchange for the homeowners promise to report back to the company, after a certain period of time, their likes and dislikes about the carpeting.

After management is satisfied that Functional and Customer Testing provided enough feedback, then the product prototype is given a brand name and packaging and it is put through a Market Test. During a Market Test, the new product is introduced into an authentic setting to learn how big the market is and how consumers and dealers react to handling, using and purchasing the product. In this way not only the product is tested but also the hypothesis, market research and work done in the early stages of the NPD (mainly the first two stages). A good example of Market Testing is "IdeaLab", which is a company that introduced new Internet based ventures such as EToys. When the company decided to launch into the Internet a web-based car buying service called "Cars Direct", a web site was created as a prototype to test the market for such a service. This web site was a live one and monitored on-line market reactions. Through the site four cars were sold in one evening, a fact that showed the product's potential for strong market acceptance.

In testing consumer products, a company should focus on the estimation of four variables: trial, first repeat purchase, adoption and purchase frequency. A company by testing wants to see whether these variables exist at high levels. For example one can see that many consumers trying a product for the first time but few re-buying it. In another case one can see high adoption but very low purchase frequency (good example of this are frozen foods). The major methods of consumer goods market testing, from the least to the most costly are given bellow.

- **Sales - Wave Research.** Consumers that initially try the product at no cost are offered the product or a competitive one for up to five times at a slightly reduced price. The number of customers that select the product again and their satisfaction towards the product is noted.
- **Simulated Test Marketing.** 40 buyers are asked to answer questions about brand familiarity and product preferences. Then they are asked to see commercials of both competitive products and of the new product and they are given money and brought to a store to make a purchase. The company then notes how many customers have bought the new product and how many the competitive ones. This is a test of the advertisement's effectiveness against competitive ones in a simulated trial. Also customers receive a free sample of the product and then are asked to report on product attributes, usage, satisfaction and purchase intention.
- **Controlled Test Marketing.** In this kind of test a research company manages a panel of outlets that will carry the new product for a fee. The new product company selects the number of stores and their geographical location. The research company delivers the new product to the selected stores and controls the positioning of the product into each store and it's pricing. Sales are recorded through electronic means and evaluated. Also local advertising and promotions during the test is evaluated.
- **Test Markets.** In this case the company chooses few cities and through full advertising and promotion, the company's sales force tries to carry the product into full exposure and large-scale sales. Here the people involved with the test must decide on the number and location of the cities, the length of the test, what to track and what action to take. Nowadays Market Tests become more and more scarce since they cost too mush and companies prefer more economical test methods with smaller test areas and shorter test periods.

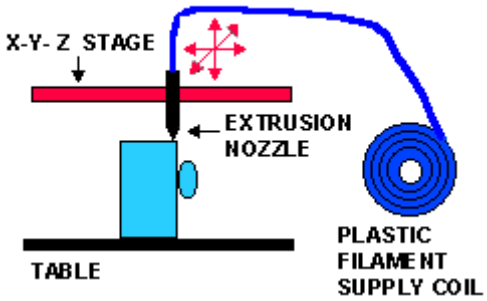
Business goods can also benefit from market testing and there are several methods available to do just that. Expensive industrial goods usually undergo just Alpha and Beta Testing. But it is better to

undergo and some form of market test as well. So these goods usually are market tested in trade shows. Trade shows draw large number of customers who view many products in a few concentrated days. The company that wants to test its new product, can observe how much interest customers show for the product, how they react to its various features and how many express purchase intentions and place orders. The disadvantage of trade shows is that the new product is revealed to the competition and so the company must be prepared to launch the new product into the market soon after the trade show.

4.1.1.2 Prototyping Techniques

4.1.1.2A Fused Deposition Modelling (FDM)

Figure 1: Diagram of FDM



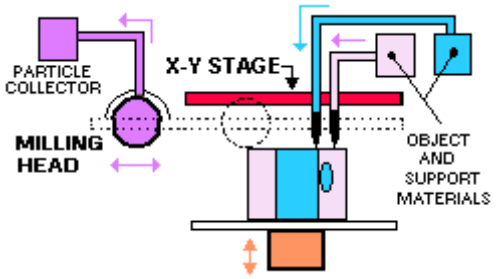
Source: "Fused Deposition Modeling", Worldwide Guide for Rapid Prototyping, On-line: http://www.additive3d.com/fdm.htm

"FDM is the second most widely used rapid prototyping technology, after stereolithography. A plastic filament is unwound from a coil and supplies material to an extrusion nozzle. The nozzle is heated to melt the plastic and has a mechanism, which allows the flow of the melted plastic to be turned on and off. The nozzle is mounted to a mechanical stage, which can be moved in both horizontal and vertical directions.
As the nozzle is moved over the table in the required geometry, it deposits a thin bead of extruded plastic to form each layer. The plastic hardens immediately after being squirted from the nozzle and bonds to the layer below. The entire system is contained within a chamber, which is held at a temperature just below the melting point of the plastic.
Several materials are available for the process including ABS and investment casting wax. ABS offers good strength, and more recently polycarbonate and polysulfone materials have been introduced which extend the capabilities of the method further in terms of strength and temperature range. Support structures are fabricated for overhanging geometries and are later removed by breaking them away from the object. A water-soluble support material, which can simply be washed away, is also available.
The method is office-friendly and quiet. FDM is fairly fast for small parts on the order of a few cubic inches, or those that have tall, thin form-factors. It can be very slow for parts with wide cross sections, however. The finish of parts produced with the method have been greatly improved over the years, but aren't quite on a par with stereolithography. The closest competitor to the FDM process is probably three-dimensional printing."

Source / Taken from: "Fused Deposition Modeling", Worldwide Guide for Rapid Prototyping, On-line: http://www.additive3d.com/fdm.htm

4.1.1.2B Inkjets

Figure 1: Inkjets Diagram



Source: "Inkjets", Worldwide Guide for Rapid Prototyping, On-line: http://www.additive3d.com/ink_int.htm

Thermal Phase Change Inkjets

"Solidscape, Inc.'s inkjet method is illustrated, but others are also available. This machine uses a single jet each for a plastic build material and a wax-like support material, which are held in a melted liquid state in reservoirs. The liquids are fed to individual jetting heads, which squirt tiny droplets of the materials as they are moved in X-Y fashion in the required pattern to form a layer of the object. The materials harden by rapidly dropping in temperature as they are deposited.
After an entire layer of the object is formed by jetting, a milling head is passed over the layer to make it a uniform thickness. Particles are vacuumed away as the milling head cuts and are captured in a filter. The process is repeated to form the entire object. After the object is completed, the wax support material is either melted or dissolved away.
The most outstanding characteristic of the Solidscape system is the ability to produce extremely fine resolution and surface finishes, essentially equivalent to CNC machines. However, the technique is very slow for large objects. While the size of the machine and materials are office-friendly, the use of a milling head creates noise, which may be objectionable in an office environment. Materials selection also is very limited.
Other manufacturers use considerably different inkjet techniques, but all rely on squirting a build material in a liquid or melted state, which cools or otherwise hardens to form a solid on impact. 3D Systems produces an inkjet machine called the **ThermoJet Modeller(tm)**, which utilizes several hundred nozzles in a wide head configuration. It uses a hair-like matrix of build material to provide support for overhangs, which can be easily brushed off once the object, is complete. This machine is much faster than the Solidscape approach, but doesn't offer as good a surface finish or resolution.
All thermal phase change inkjets have material limitations and make fragile parts. The applications range from concept models to precise casting patterns for industry and the arts, particularly jewellery."

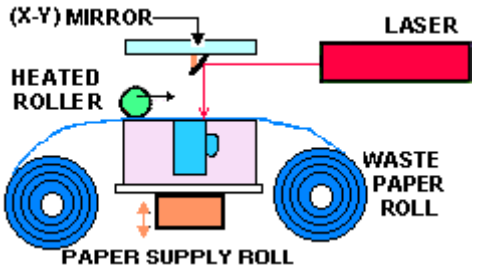
Photopolymer Phase Change Inkjets

"Objet Geometries Ltd., an Israeli company, announced the **Quadra(tm)** system in early 2000. It's potentially a promising replacement for stereolithography. The process is based on photopolymers, but uses a wide area inkjet head to layer wise deposit both build and support materials. It subsequently completely cures each layer after it is deposited with a UV flood lamp mounted on the print head. The support material, which is also a photopolymer, is removed by washing it away in a secondary operation. The low price, approximately $65K, and specifications that are similar to laser-based stereolithography systems costing ten times as much make this an important technology to watch.
In July 2002, 3D Systems introduced a similar photopolymer-based system called the **InVision(tm)**. It uses the technology originally developed for the **ThermoJet Modeller(tm)**."

Source / Taken from: "Inkjets", Worldwide Guide for Rapid Prototyping, On-line: http://www.additive3d.com/ink_int.htm

4.1.1.2C Laminated Object Manufacturing

Figure 1: Laminated Object Manufacturing Diagram



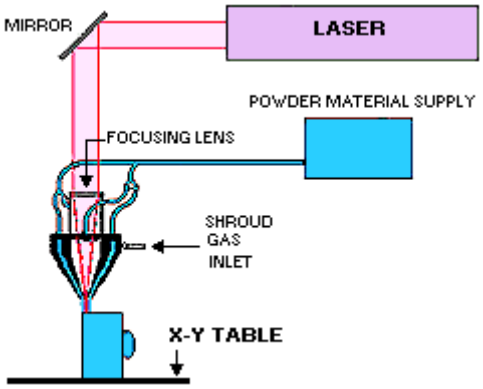
Source: "Laminated Object Manufacturing", Worldwide Guide for Rapid Prototyping, On-line: http://www.additive3d.com/lom_int.htm

"Profiles of object cross sections are cut from paper or other web material using a laser. The paper is unwound from a feed roll onto the stack and first bonded to the previous layer using a heated roller, which melts a plastic coating on the bottom side of the paper. The profiles are then traced by an optics system that is mounted to an X-Y stage.
After cutting of the layer is complete, excess paper is cut away to separate the layer from the web. Waste paper is wound on a take-up roll. The method is self-supporting for overhangs and undercuts. Areas of cross-sections, which are to be removed in the final object, are heavily crosshatched with the laser to facilitate removal. It can be time consuming to remove extra material for some geometries, however.
Many companies and research groups have developed variations on this method. For example, Kira's Paper Lamination Technology (PLT) uses a knife to cut each layer instead of a laser and applies adhesive to bond layers using the xerographic process. There are also variations, which seek to increase speed and/or material versatility by cutting the edges of thick layers diagonally to avoid stair stepping.
In general, the finish, accuracy and stability of paper objects are not as good as for materials used with other RP methods. However, material costs are very low, and objects have the look and feel of wood and can be worked and finished in the same manner. This has fostered applications such as patterns for sand castings. While there are limitations on materials, work has been done with plastics, composites, ceramics and metals. Some of these materials are available on a limited commercial basis.
The principal commercial provider of LOM systems, Helisys, ceased operation in 2000. However, there are several other companies with either similar LOM technology, or in early commercial stages. These companies are addressing market segments ranging from concept modelling to very large objects for architectural applications."

Source / Taken from: "Laminated Object Manufacturing", Worldwide Guide for Rapid Prototyping, On-line: http://www.additive3d.com/lom_int.htm

4.1.1.2D Laser Engineered Net Shaping

Figure 1: Laser Engineered Net Shaping Diagram



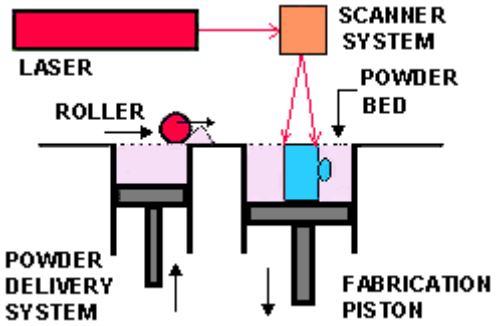
Source: "Laser Engineered Net Shaping", Worldwide Guide for Rapid Prototyping, On-line: http://www.additive3d.com/lens.htm

"Laser Engineered Net Shaping (LENS) is a technology that is gaining in importance and in early stages of commercialisation. A high power laser is used to melt metal powder supplied coaxially to the focus of the laser beam through a deposition head.
The laser beam typically travels through the centre of the head and is focused to a small spot by one or more lenses. The X-Y table is moved in raster fashion to fabricate each layer of the object. The head is moved up vertically as each layer is completed. Metal powders are delivered and distributed around the circumference of the head either by gravity, or by using a pressurized carrier gas. An inert shroud gas is often used to shield the melt pool from atmospheric oxygen for better control of properties, and to promote layer-to-layer adhesion by providing better surface wetting.
A variety of materials can be used such as stainless steel, Inconel, copper, aluminium etc. Of particular interest are reactive materials such as titanium. Materials composition can be changed dynamically and continuously, leading to objects with properties that might be mutually exclusive using classical fabrication methods.
The strength of the process lies in the ability to fabricate fully dense metal parts with good metallurgical properties at reasonable speeds. Objects fabricated are near net shape, but generally will require finish machining. They have good grain structure, and have properties similar to, or even better than the intrinsic materials. Selective laser sintering is at present the only other commercialised RP process that can produce metal parts directly. LENS has fewer material limitations than SLS and doesn't require secondary firing operations as some of those processes do, however."

Source / Taken from: "Laser Engineered Net Shaping", Worldwide Guide for Rapid Prototyping, On-line: http://www.additive3d.com/lens.htm

4.1.1.2E Selective Laser Sintering

Figure 1: Selective Laser Sintering Diagram



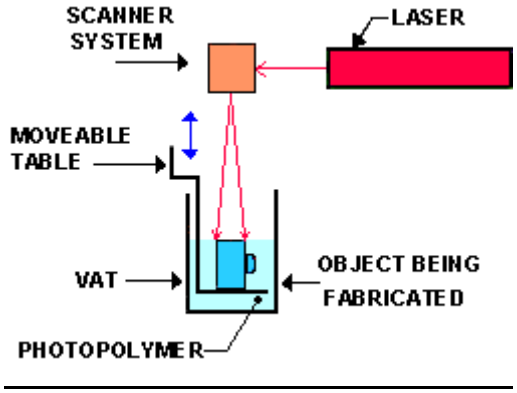
Source: "Selective Laser Sintering", Worldwide Guide for Rapid Prototyping, On-line: http://www.additive3d.com/sls_int.htm

"A roller spreads thermoplastic powder over the surface of a build cylinder. The piston in the cylinder moves down one object layer thickness to accommodate the new layer of powder. The powder delivery system is similar in function to the build cylinder. Here, a piston moves upward incrementally to supply a measured quantity of powder for each layer.
A laser beam is then traced over the surface of this tightly compacted powder to selectively melt and bond it to form a layer of the object. The fabrication chamber is maintained at a temperature just below the melting point of the powder so that heat from the laser need only elevate the temperature slightly to cause sintering. This greatly speeds up the process. The process is repeated until the entire object is fabricated.
After the object is fully formed, the piston is raised to elevate it. Excess powder is simply brushed away and final manual finishing may be carried out. No supports are required with this method, since overhangs and undercuts are supported by the solid powder bed.
SLS offers the key advantage of making functional parts in essentially final materials. However, the system is mechanically more complex than stereolithography and most other technologies. A variety of thermoplastic materials such as nylon, glass filled nylon, and polystyrene are available. Surface finishes and accuracy are not quite as good as with stereolithography, but material properties can be quite close to those of the intrinsic materials. The method has also been extended to provide direct fabrication of metal and ceramic objects and tools.
Since the objects are sintered they are porous. It may be necessary to infiltrate the part, especially metals, with another material to improve mechanical characteristics."

Source / Taken from: "Selective Laser Sintering", Worldwide Guide for Rapid Prototyping, On-line: http://www.additive3d.com/sls_int.htm

4.1.1.2F Stereolithography

Figure 1: Stereolithography Diagram



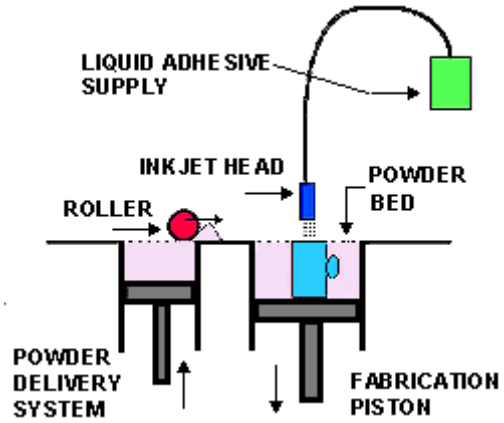
Source: "Stereolithography", Worldwide Guide for Rapid Prototyping, On-line: http://www.additive3d.com/sla_int.htm

"Stereolithography is the most widely used rapid prototyping technology. Stereolithography builds plastic parts or objects a layer at a time by tracing a laser beam on the surface of a vat of liquid photopolymer. This class of materials, originally developed for the printing and packaging industries, quickly solidifies wherever the laser beam strikes the surface of the liquid. Once one layer is completely traced, it's lowered a small distance into the vat and a second layer is traced right on top of the first. The self-adhesive property of the material causes the layers to bond to one another and eventually form a complete, three-dimensional object after many such layers are formed.
Some objects have overhangs or undercuts, which must be supported during the fabrication process by support structures. These are either manually or automatically designed, and fabricated right along with the object. Upon completion of the fabrication process, the object is elevated from the vat and the supports are cut off.
Stereolithography generally is considered to provide the greatest accuracy and best surface finish of any rapid prototyping technology. Over the years, a wide range of materials with properties mimicking those of several engineering thermoplastics, have been developed. Limited selectively colour-changing materials for biomedical and other applications are available, and ceramic materials are currently being developed.
The technology is also notable for the large object sizes that are possible."

Source / Taken from: "Stereolithography", Worldwide Guide for Rapid Prototyping, On-line: http://www.additive3d.com/sla_int.htm

4.1.1.2G Three Dimensional Printing

Figure 1: Three Dimensional Printing Diagram



Source: "Three Dimensional Printing", Worldwide Guide for Rapid Prototyping, On-line: http://www.additive3d.com/3dp_int.htm

"Three-dimensional printing was developed at MIT. It's often used as a direct manufacturing process as well as for rapid prototyping.
The process starts by depositing a layer of powder object material at the top of a fabrication chamber. To accomplish this, a measured quantity of powder is first dispensed from a similar supply chamber by moving a piston upward incrementally. The roller then distributes and compresses the powder at the top of the fabrication chamber. The multi-channel jetting head subsequently deposits a liquid adhesive in a two dimensional pattern onto the layer of the powder which becomes bonded in the areas where the adhesive is deposited, to form a layer of the object.
Once a layer is completed, the fabrication piston moves down by the thickness of a layer, and the process is repeated until the entire object is formed within the powder bed. After completion, the object is elevated and the extra powder brushed away leaving a "green" object. No external supports are required during fabrication since the powder bed supports overhangs.
Three-dimensional printing offers the advantages of speedy fabrication and low materials cost. In fact, it's probably the fastest of all RP methods. Recently colour output has also become available. However, there are limitations on resolution, surface finish, part fragility and available materials. The closest competitor to this process is probably fused deposition modelling".

Source / Taken from: "Three Dimensional Printing", Worldwide Guide for Rapid Prototyping, On-line: http://www.additive3d.com/3dp_int.htm

4.1.1.3 Case Studies - Examples

Case study: "Rapid Prototyping in the ceramics industry"

A study by the Royal Doulton Company has shown that, although Stereolithography may be too expensive for use in the development of new tableware designs, there are specialist applications, in particular, airline tableware, where the technology could be of great value. The study, which was undertaken by Royal Doulton designer Richard Delaney as part of his Postgraduate Diploma in

Design, compared the cost of developing a new teapot design by using conventional prototyping methods and by using Stereolithography.

The concept design for the new pot was produced using Royal Doulton's concept visualisation software. Before the design could be converted into the computer file needed to produce the Stereolithography model, all the information was transferred into Delcam's Power Solution software. Power Solution is a much more precise modelling and machining package that was initially acquired by the company for the design and manufacture of dies for the granulate pressing of tableware. One of the reasons for using Power Solution to generate the data needed for the Stereolithography equipment was to ensure that all the surface fillets and intersections were precisely closed. This is essential for successful operation of the rapid prototyping process. A second reason for using Power Solution was to recreate the handle as the concept design software gave a slightly inaccurate result, not always giving a constant thickness throughout the handle. Thirdly, the Power Solution data used to produce the prototype can also be used to generate NC data for machining production moulds or models.

The Stereolithography model was produced by the rapid prototyping bureaux at Rover Group in four parts - the main body of the teapot, a plug to fit in the hole in the base that is required to allow excess polymer to drain away, the spout and the lid. The parts were also assembled by the bureaux and bead blasted to give a superior finish. The resulting prototype had a sufficiently good appearance for use as a presentation model. In a genuine project, the prototype would be sprayed white and lacquered to give an appearance closer to china. For this study, the surface was left in the state that it was delivered to the Royal Doulton Company, so it could be used to help explain the Stereolithography process.

The main advantage of the rapid prototyping approach was the speed of preparation of the model. With this example, which is of average complexity, the prototype was produced in about a third of the time taken using conventional modelling. Richard Delaney estimated that simple round designs could be modelled conventionally in less time than would be needed for Stereolithography. Equally, the gains with more complex shapes, including relief modelled decoration, would be even greater. In the same way, the speed of modification of the design would depend on its complexity.

With conventional modelling, the item involved is usually completely remodelled, with each modification taking almost as long as the production of the first prototype. Using CAD, any adjustments can be made to the design relatively quickly. For pieces like the teapot, Stereolithography also gives the ability to use the model as a china piece would be used. The prototype has an exact wall thickness throughout the model so giving the same internal appearance. This allows an accurate check to be made of its pouring capability, which is not possible with a conventional solid prototype. In addition, the model can be supported by its handle, enabling the feel and balance of the pot in use to be tested.

Despite these advantages, Peter Allen, Director of Design Development & Technology at Royal Doulton, felt that the additional cost of Stereolithography, which totalled around one third more than conventional techniques, could only be justified in special circumstances. Most new designs for tableware are launched at a small number of key exhibitions. Since these dates are known well in advance, the design development and prototyping work can be scheduled in plenty of time. One area where time is more critical is in the supply of airline tableware. Royal Doulton has become one of the world's largest suppliers of fine and bone china to the airline industry, supplying carriers such as British Airways, All Nippon and Air Canada. Additionally, through its partnership with De Ster, the Dutch manufacturers of rotable plastics for airline use, the company's client base now

numbers around seventy airlines. The introduction of new shape designs for this market is usually associated with a complete re-design of the aircraft interior, and always requires a rapid response. "Customers from the airlines are not always sure what they want until they see our ideas visualised on the computer" explained Mr. Allen. "Once a new design concept has been selected, we need to make prototypes for approval as quickly as possible so that we can move into full-scale production fast enough to meet the airline's deadline. In such cases, the additional cost of Stereolithography could easily be justified.

Having built up the leading position in this market, we are keen to use any new technology that will complement our traditional skills and allow us to offer an even better service to our customers." The Royal Doulton Company The Royal Doulton Company is the world's leading manufacturer and distributor in the premium ceramic tableware and giftware market. The company employs over 5,500 people on ten manufacturing sites, mainly based in Stoke-on Trent. In addition to the Royal Doulton brand, the company manufactures other major brand names, including Royal Albert, Royal Crown Derby and Minton. Around 50 % of the company's sales are made outside the UK.

Source: Programming Plus Inc, "Rapid Prototyping in the Ceramics Industry", On-line: http://www.programmingplus.com/Roi_web/Demos/Delcam_web/info/case/doulton.htm

4.1.1.4 Software Tools

http://www.materialise.com/rapid-prototyping
Materialise Software develops innovative applications enabling advanced use of the rapid prototyping and tooling techniques. The Materialise software products provide a variety of solutions for data handling in product communication, rapid prototyping and rapid tooling. Besides this, the Materialise Software Development Services offer professional software solutions, tuned to your needs. For this, Materialise has the largest software development team in the RP sector with locations in Belgium and Kiev (Ukraine).

4.1.1.5 References

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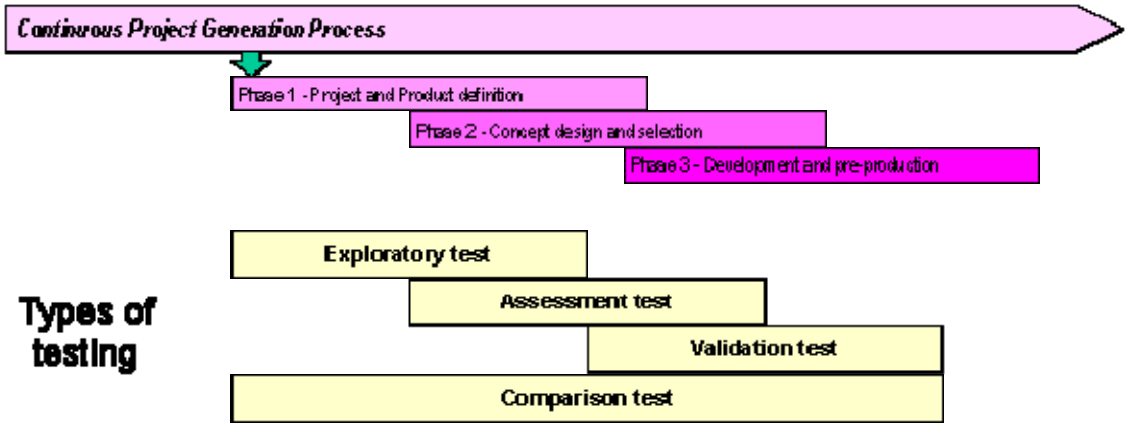
4.1.2 Product Development Testing

Product development testing is a testing process that starts at the front end of product development and ends at the very end of it. It includes different types of tests that can be applied at different levels of product development. These tests help the development team to fully understand what exactly is going on and if whether things are on track. Also the different ways that data are captured can sometimes reveal aspects of the development process that the tests on their own cannot identify.

As mentioned product development testing consists of different tests that can be applied to different levels of product development. These test are carried out to examine different objectives, approaches and types of modelling. There are five main types of testing that can be described in more detail and these are:

1. **The Exploratory Tests**
2. **The Assessment Tests**
3. **The Validation Tests**
4. **The Comparison Tests**
5. **ISO 9000 Tests**

In respect to the development process the timing of these different tests can be visualized using the following figure.



Source: Better Product Design, Institute of Manufacturing, University of Cambridge, On-line http://www.betterproductdesign.net/tools/concept/testing.html

5.1.2.1 Exploratory Tests

Exploratory tests are those that are carried out early in the development process during Levels 1 and 2. This is when the problem of NPD is still being defined and different solutions are being considered. They usually take place after the team has a clear understanding of user profile or customer needs. Their objective is to examine and to explore the preliminary design concepts and answer some basic questions that include:

- What to customers think about using the product concept?
- Does the basic product functionality have value to the user or customer?
- Is the product's user interface appropriate and easy to operate?
- How does the user feel about the product concept?
- Are the team's assumptions about the customer needs correct?
- Has the team misunderstood any customer wants or needs?

This kind of early analysis of concepts and how are these fit into the user or customer profile or specific wants and needs is very critical. It is the most critical one compared to all prototyping or product evaluation analysis tests that can be performed later on. This due to the act that faulty assumptions at this stage will most certainly be the root of a lot of problems further down the development process.

Data collection at this point is usually qualitative and is based on observation, interview and discussion with the target audience. The ideal scenario for this kind of tests is for the customer to test the product concept without training or prompting so that he can assess freely all the controls and instructions. Some metrics can be applied such as time to perform tasks or number of errors or failures allowed.

Source: Better Product Design, Institute of Manufacturing, University of Cambridge, On-line http://www.betterproductdesign.net/tools/concept/testing.htm

5.1.2.2. Assessment Tests

Unlike to the exploratory tests that are designed to explore all potentially solutions for new product development, the Assessment Tests are designed to look with more detail into the preferred single solution. This is why they are usually performed at a later stage of development than the exploratory ones.

The aim of the assessment tests is to ensure that all assumptions are relevant to the preferred solution and that specific design choices are appropriate for that solution. These tests focus on usability and functionality that is offered by the solution in hand. This in some cases can be considered as an early new product evaluation. Assuming that the right product concept is chosen the assessment tests tend to seek answers to questions like the following:

- Is the product concept usable?
- Does the product concept satisfy all user needs?
- How does the user use the product and could it be more effective?
- How will the product be assembled and tested and could this be achieved in a better way?
- Can the user complete all the product tasks as intended?

Assessment tests require complex product modelling, analytical methods of testing, simulations and working product replicas. The evaluation of the tests results can be informal using both internal and external evaluation panels or teams. Data collection as in the case of the exploratory tests can be qualitative and based on observation, interviews and discussions.

Source: Better Product Design, Institute of Manufacturing, University of Cambridge, On-line http://www.betterproductdesign.net/tools/concept/testing.html

5.1.2.3 Validation Tests

Validation tests are conducted at the late stages of new product development process and are designed to examine that all design goals have been met. These kinds of tests may examine the product's functionality, reliability, usability, performance, maintainability, assembly methods, robustness and others. Validation tests examine the product as if it was just out of the production line. So product activities should and are expected to be working in full.

A performed validation test is the first opportunity to examine product components altogether. Single component testing can be performed at this point. During validation tests the product must have its final form including packaging, documentation and labels. Included in the validation tests are all formal test that are required for certification for safety or environmental purposes. Compared to the assessment tests, validation ones focus on experimental rigor and consistency. Sometimes it is preferable for the testing to be carried out by an external team and away from the original design team.

Data collection is usually quantitative based on measures of performance. This is done by benchmarking the new product against some kind of expected performance or pre-set standards. Any failures on product performance must be noted and errors should be corrected before the product reaches the manufacturing process.

Source: Better Product Design, Institute of Manufacturing, University of Cambridge, On-line http://www.betterproductdesign.net/tools/concept/testing.htm

5.1.2.4 Comparison Tests

A **comparison test** can be conducted at any point of the product development process. These tests aim to compare companies, practices, concepts, products, or product elements against some existing alternative. For example "Benchmarking", as it is offered by Urenio Research Unit, is a comparison test that can be carried out at the beginning or the end of the process. The alternatives against any of the above can be compared against could be either a existing solution or a competitive one.

Comparison testing can include the examination of data from both product performance and product preference. The tests are used to examine performance, to test superiority, or to understand product advantages and disadvantages of different product designs.

Source: Better Product Design, Institute of Manufacturing, University of Cambridge, On-line http://www.betterproductdesign.net/tools/concept/testing.htm

5.1.2.5. ISO 9000 Tests

ISO 9000 defines a series of test activities such as design review, design verification, design validation, quality control, safety etc. Some of these activities are further discussed bellow.

- **Design review.** A design review is a set of tests activities that aim to test the product design against pre-determined quality requirements. During the tests it is imperative that all problems must be identified and all the necessary action should be proposed to the design team.
- **Design verification.** Design verification tests are tests whose purpose is to examine product design and development outputs and to use objective evidence to confirm that these outputs meet the product design and development initial specifications.
- **Design validation.** Design validation tests are tests that are performed to examine whether the resulting product meets all user needs or wants.

Source: Better Product Design, Institute of Manufacturing, University of Cambridge, On-line http://www.betterproductdesign.net/tools/concept/testing.htm

5.1.3 Market Research Issues

5.1.3.1 Market Targeting Strategy

Market targeting strategy sometimes is confused with marketing strategy since it can be a part of it. It is a completely different thing. The marketing strategy is the creation of a market plan which is described in Level 7 and which is used in product commercialization. Market target strategy is used in market testing and it relates with the selection of the customers that will participate in the tests. Also sometimes market target strategy is used in the final selection of the market during product concept development or marketing plan creation. In that case the same apply.

The targeting strategy must include the number of market segments to target, the number of product to offer and a plan of which product to be offered where. There are three main steps of targeting: the market segmentation, the target choice and the product positioning.

Target strategy is influenced by the market maturity, the diversity of customer needs and preferences, the company's size, the strength of the competition and the volume of products required for the tests.

5.1.3.1A Market segmentation

A very important issue related to market research and to market testing is **market segmentation**. Market segmentation is the process of selecting a group or groups of consumers or customers having similar characteristics for the market testing to be performed. Its purpose is to determine specific segments of the market upon which to concentrate marketing efforts, research and testing, to adopt a customer-oriented philosophy, to divide a large market into small sub-segments and to develop a dominant position in a specialized market segments.

The most important requirements of market segmentation are three:

- **Market measurements:** Identification and measurement of the characteristics and of the size of the market segment.

- **Economic opportunity:** The segment that is selected must have the income and the size so that to make a specific product profitable.
- **Market access:** The segment must be reachable i.e. must be easily handled, approached and manipulated by marketing methods.

A market can be segmented using the following steps:

Step 1: A demographic profile must be created. For example a typical profile of a customer of a specific market segment is given in the table bellow.

Market Segment Characteristics	Consumer Profile
Age:	45-50
Income level:	€ 30.000 +
Education level:	Post secondary education

Step 2: Identification of high concentrations of potential customers that fit the market segment characteristics. Usually people with similar characteristics such as income level are located in specific places. This information is very handy for the placement of products.

Step 3: Determination of consumer habits. How, where, when, and what potential consumers prefer to buy should be identified and noted.

Assessment 1 evaluates the ideas generated in Level 1 and both the way and the tools used for idea generation.

According to the answers a user gives to the questions a GO, HOLD or KILL decision is provided for further progression in the roadmap and specifically to Level 2.

Source: Better Product Design, Institute of Manufacturing, University of Cambridge, On-line http://www.betterproductdesign.net/tools/market/segmentation.htm

NPD Stage 5: Technical Implementation

As soon as all the market and beta testing of the new product prototype is concluded then the new product must enter into the technical implementation Level. In this Level the product is manufactured in large quantities so that it can be released into the selected market or market segment. The problems one could face in this Level are manufacturing, production or manufacturing management related. Tools and methods are provided in this Level to tackle some of the most occurring problems.

6.1 Tools & Solutions

Issues that need to be looked at and solved in this Level are things to do with manufacturing and the ways this can be done easily and effectively inside the cost and time limits set, and according to the specifications that have been laid out during the previous levels of development.

Also this Level deals and gives some insight solutions with some major manufacturing issues such as mass manufacturing, bill of materials management, quality assurance and value engineering and major tools that can be a great help for engineers and production personnel are discussed. These include CAD/CAM, Design for X, Industrial Design, Reengineering, Reverse Engineering and others.

Solutions for specific industry related issues are not given since the Level contents are set to give general directions in solving management problems that can arise in all industries and to provide some insight of the situations that must be dealt in product production.

6.1.1 Design for X

The term "Design for Manufacture" was used in the past to describe a design approach that ensured that a product is both manufacturable and simple to assemble. Nowadays the term "Design for X" is used to include activities such as the design for manufacture that express product design using a collection of tools, techniques and philosophies to link customer requirements and quality criteria such as robustness, serviceability and others.

There are dozens of Design for X methodologies; tools and techniques, each of them have impact on specific markets and for specific types of products. Some of the Design for X methodologies are given bellow

- Design for manufacture.
- Design for assembly.
- Design for disassembly.
- Design for life cycle.
- Design for ease of use.
- Design for installation.
- Design for maintenance.
- Design for validation.

- Design for reliability.
- Design for reuse.
- Design for cost.
- Design for the environment.
- Design for quality.
- Design for speed.

The most important of all the design approaches that are given above are the Design for Manufacture and the Design for Assembly since they have direct and recognizable impact on product costs.

Source: Better Product Design, Institute of Manufacturing, University of Cambridge, On-line http://www.betterproductdesign.net/guide/design4X.html

6.1.1.1 Design for Manufacture

Design for Manufacture (DfM) is more than a philosophy than a practice. It is a way of thinking, which can be applied to any product component, product or product family tree. Its purpose is to minimize the overall component count and to optimize the remaining components so that the manufacturing costs to be reduced. For this to be accomplished the product design team must have deep understanding of the things that contribute to the overall product cost and the relative trade-offs between manufacturing processes, production volume and fixed and variable costs. The design for manufacture is defined by three key elements: the process selection, the reduction of process stages and the design of the process.

Process selection involves the selection of both material and methods for manufacturing the individual product components and it is based on the following:

- Performance criteria such as conductivity, strength, friction or thermal properties.
- Tolerance specifications.
- Component complexity requirements.
- Set up and tooling costs.
- Production volume.
- Expertise required and capability.

The reduction of the manufacturing process stages can be achieved by eliminating the unnecessary stages through a combination of alternative strategies. Such strategies can be the component minimization (method that is used widely in the electronics industry), the elimination of finishing processes (for components that may not be visible to the customer), the combining of manufacturing processes and the single direction processing or machining (this helps to reduce set up requirements).

The design of the process is defined by certain guidelines, which aim to ensure optimum design of components to satisfy any constraints that govern the manufacturing process. These guidelines help designers - engineers to avoid errors, recognize pitfalls and take advantage of benefits. Sometimes they are identified as good practices for certain manufacturing processes. Many guidelines are available for all, others are well kept company secrets. They can cover almost all industry segments

but sometimes they can be difficult to use since one should expect the unexpected when it comes in producing a new product.

Source: Better Product Design, Institute of Manufacturing, University of Cambridge, On-line http://www.betterproductdesign.net/guide/design4X.htm

6.1.1.2 Design of Assembly

The **Design of Assembly (DfA)** can be considered as part of DfM since it also supports the minimization of the total number of product components. In addition DfA focuses on the optimisation of how product components can be moved, held, located and joint during the manufacturing process.

Like DfM, there are certain guidelines that can be used for DfA. These guidelines are nothing more than rules that govern part count, how wires and cables are set, how adjustments should be made, how parts are inserted, and how components can be assembled in closed spaces. Like DfM, DfA guidelines can also be difficult to implement since there are always unexpected issues that can appear during the manufacturing - assembly process.

Systematic approaches can provide a unique environment for decision-making process for DfA. These are many methods for someone to follow a systematic approach for DfA. The two best-known ones are the one that was developed in the 70's by Boothroyd and Dewhurst, and the one developed in the 80's by Lucas Engineering Systems. For the record a systematic approach for DfA begins with an analysis of the assembly to determine if products components can be eliminated based upon the following simple rules:

* Determine the relative movement between one part and another.
* Determine whether a material must be different from another.
* Determine whether a specific part needs to be altered or replaced.

The approach ends with mapping of the assembly sequence to determine matters such as the design and setting up of the feeding for automated assembly, the setting up of the insertion order of components and the setting up of fitting, securing and locating components.

Source: Better Product Design, Institute of Manufacturing, University of Cambridge, On-line http://www.betterproductdesign.net/guide/design4X.htm

6.1.1.3 Design for Life Cycle

For many durable goods, there are a variety of other design considerations related to the total product life cycle. For consumable products, some of these life cycle factors may be of lesser importance. Life cycle factors that may need to be addressed during product design include: Testability / Inspectability, Reliability / Availability, Maintainability / Serviceability, Design for the Environment, Upgradeability, Installability, Safety and Product Liability and Human Factors.

The relative importance of these factors and their orientation will vary from industry to industry and product to product. However, there are general design principles for these life cycle requirements that will be generally applicable to many items. A basic integrated product

development concept is the parallel design of support processes with the design of the product. This parallel design requires early involvement and early consideration of life cycle factors (as appropriate) in the design process. However, in many organizations, consideration or design of the support processes is an after-thought and many of these developmental activities are started after the design of the product is well under way if not essentially complete.

Source: Crow Kenneth, "Design for the Life Cycle", DRM Associates, On-line http://www.npd-solutions.com/lifecycle.html

6.1.1.3A Design for Testability / Inspectability

Test and inspection processes can consume a significant amount of effort and the development or acquisition of test equipment can require considerable time and expense with some products. Early involvement of the test engineering or quality assurance functions can lead to design choices that can minimize the cost of developing or acquiring necessary equipment and the effort to test or inspect the product at the various stages of production. A starting point is to establish a common understanding between Engineering, their customers, and other functional departments regarding the requirements for product qualification, product acceptance after manufacture, and product diagnosis in the field. With this understanding, a design team can begin to effectively design products and test and inspection processes in parallel.

Increasingly complex and sophisticated products require capabilities and features to facilitate test and acceptance of products and diagnosis products if a defect is identified. Specific principles, which need to be understood and applied in the design of products, are:

- Use of Geometric Dimensioning and Tolerancing (GD&T) to provide unambiguous representation of design intent.
- Specification of product parameters and tolerances that are within the natural capabilities of the manufacturing process (process capability index Cp and Cpk)
- Provision of test points, access to test points and connections, and sufficient real estate to support test points, connections, and built-in test capabilities
- Standard connections and interfaces to facilitate use of standard test equipment and connectors and to reduce effort to set-up and connect the product during testing.
- Automated test equipment compatibility.
- Built-in test and diagnosis capability to provide self-test and self-diagnosis in the factory and in the field.
- Physical and electrical partitioning to facilitate test and isolation of faults.

In addition, test engineering should be involved at an early stage to define test requirements and design the test approach. This will lead to the design or specification of test equipment that better optimizes test requirements, production volumes, equipment cost, equipment utilization, and testing effort/cost. Higher production volumes and standardized test approaches can justify development, acquisition, or use of automated test equipment. The design and acquisition of test equipment and procedures can be done in parallel with the design of the product, which will reduce lead-time. Design of products to use standardized equipment can further reduce the costs of test equipment and reduce the lead-time to acquire, fabricate, and set-up test equipment for both qualification testing and product acceptance testing.

6.1.1.3B Design for Reliability

Reliability consideration has tended to be more of an after-thought in the development of many new products. Many companies' reliability activities have been performed primarily to satisfy internal procedures or customer requirements. Where reliability is actively considered in product design, it tends to be done relatively late in the development process. Some companies focus their efforts on developing reliability predictions when this effort instead could be better-utilized understanding and mitigating failure modes. And so developing improved product reliability. Organizations will go through repeated (and planned) design/build/test iterations to develop higher reliability products. Overall, this focus is reactive in nature, and the time pressures to bring a product to market limit the reliability improvements that might be made.

In an integrated product development environment, the orientation toward reliability must be changed and a more proactive approach utilized. Reliability engineers need to be involved in product design at an early point to identify reliability issues and concerns and begin assessing reliability implications as the design concept emerges.

Use of computer-aided engineering (CAE) analysis and simulation tools at an early stage in the design can improve product reliability more inexpensively and in a shorter time than building and testing physical prototypes. Tools such as finite element analysis, fluid flow, thermal analysis, integrated reliability prediction models, etc., are becoming more widely used, more user friendly and less expensive. Design of Experiments techniques can provide a structured, proactive approach to improving reliability and robustness as compared to unstructured, reactive design/build/test approaches. Further, these techniques consider the effect of both product and process parameters on the reliability of the product and address the effect of interactions between parameters. Finally, the company should begin establishing a mechanism to accumulate and apply "lessons learned" from the past related to reliability problems as well as other producibility and maintainability issues. These lessons learned can be very useful in avoiding making the same mistakes twice.

Specific Design for Reliability guidelines include the following:

- Design based on the expected range of the operating environment.
- Design to minimize or balance stresses and thermal loads and/or reduce sensitivity to these stresses or loads.
- De-rate components for added margin.
- Provide subsystem redundancy.
- Use proven component parts & materials with well-characterized reliability.
- Reduce parts count & interconnections (and their failure opportunities).
- Improve process capabilities to deliver more reliable components and assemblies.

6.1.1.3C Design for Maintainability / Serviceability

Consideration of product maintainability/serviceability tends to be an after-thought in the design of many products. Personnel responsible for maintenance and service need to be involved early to share their concerns and requirements. The design of the support processes needs to be developed in parallel with the design of the product. This can lead to lower overall life cycle costs and a product design that is optimized to its support processes.

When designing for maintainability/serviceability, there needs to be consideration of the trade-offs involved. In high reliability and low cost products or with consumable products, designing for maintainability/serviceability is not important. In the case of a durable good with a long life cycle or a product with parts subject to wear, maintainability/serviceability may be more important than initial product acquisition cost, and the product must be designed for easy maintenance. In these situations, basic design rules need to be considered such as:

- Identify modules subject to wear or greater probability of replacement. Design these modules, assemblies or parts so that they can be easily accessed, removed and replaced.
- Use quick fastening and unfastening mechanisms for service items.
- Use common hand tools and a minimum number of hand tools for disassembly and re-assembly.
- Minimize serviceable items by placing the most likely items to fail, wear-out or need replacement in a small number of modules or assemblies. Design so that they require simple procedures to replace.
- Use built-in self-test and indicators to quickly isolate faults and problems.
- Eliminate or reduce the need for adjustment.
- Use common, standard replacement parts.
- Mistake-proof fasteners so that only the correct fastener can be used in re-assembly. Mistake-proof electrical connectors by using unique connectors to avoid connectors being mis-connected.

In addition, service and support policies and procedures need to be developed, service training developed and conducted, maintenance manuals written, and spare parts levels established. As these tasks are done in parallel with the design of the product, it reduces the time to market and will result in a more satisfied customer when inevitable problems arise with the first delivery of a new product.

Source: DRM Associates (http://www.npd-solutions.com/lifecycle.html)

6.1.1.4. Design for the Environment

There are three major elements of design for the environment: design for environmental manufacturing, design for environmental packaging, and design for disposal and recycle ability. Design for environmental manufacturing involves the following considerations:

- Non-toxic processes & production materials.
- Minimum energy utilization.
- Minimize emissions.
- Minimize waste, scrap & by-products.

Design for environmental packaging involves the following considerations:

- Minimum of packaging materials.
- Reusable pallets, totes and packaging.
- Recyclable packaging materials.
- Bio-degradable packaging materials.

Design for disposal & recycle ability involves the following considerations:

- Re-use / refurbishment of components & assemblies.
- Material selection to enable re-use (e.g., thermo set plastics vs. thermoplastics) and minimize toxicity.
- Avoids filler material in plastics such as fibreglass and graphite.
- Minimum number of materials / colors to facilitate separating materials and re-use.
- Material identification to facilitate re-use.
- Design to enable materials to be easily separated.
- Design for disassembly (e.g., fracture points, fastening vs. bonding).
- Avoid use of adhesives.
- Limit contaminants - additives, coatings, metal plating of plastics, etc.
- Maximize use of recycled or ground material with virgin material.
- Design for serviceability to minimize disposal of non-working products

To support design for recycle ability, design for dis-assembly needs to be addressed. Design for disassembly enhances maintainability or serviceability of a product, and it enables recycling of materials, component parts, assemblies, and modules. There are a number of principles to facilitate disassembly:

- Provide ready access to parts, fasteners, etc. to support disassembly.
- Design modular products to enable modules to be disassembled for service or re-use.
- Minimize weight of individual parts and modules to facilitate disassembly
- Use joining and fastening techniques to facilitate disassembly (e.g., fasteners instead of adhesives)
- Minimize fragile parts and leads to enable re-use and re-assembly.
- Use connectors instead of hard-wired connections.
- Design to enable use of common hand tools for disassembly.

Source: DRM Associates (http://www.npd-solutions.com/dfe.html)

6.1.1.5 References

- "Design for Manufacturability Handbook", Bralla.
- "Design for X" (http://www.betterproductdesign.net), Good Design Practice Program, Institute for Manufacturing & Engineering Design Center, University of Cambridge, UK, 2004
- Buxter M, "Product Design: Practical Methods for the Systematic Development of New Products", Stanley Thormes, UK, 1999.
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(http://www.npd-solutions.com/lifecycle.html), DRM Associates, 2002

6.1.2 Industrial Design

> "When someone chooses to buy a product, he takes for granted that the product will perform the function or functions it is intended for. The customer is usually attracted by the products appearance, specification and price. But he is also attracted by less obvious product characteristics, such as sound, smell and feel. These subjective characteristics of a product make the product a joy to use since they satisfy customer senses and so form a bond between the customer and the product beyond rational purchasing criteria. By paying more attention to these characteristics, manufacturers stand to benefit.
>
> The work of Industrial Design has shown the importance of the quality of user experience when interacting with product. For example, the balance of a wine glass or the action of a hinge is qualities, which are often taken for granted until they are found to be lacking. A company should consider these issues when designing from the users perspective.
>
> The aim to develop guidelines to ensure that the subjective characteristics mentioned above, is for industrial design to become a recognised part of the design cycle in the same way that sophisticated procedures are used by some manufacturers to evaluate and refine the visual aesthetics.
>
> Whilst some quite ordinary products already possess many of these sensory attributes, it would appear that manufacturing industry does not sufficiently recognize and prioritize them. Even in more expensive consumer goods they are often missed."

Author: Bailey Mark, ", The Center for Industrial Design, NorthCumbria University, UK

Source: Bailey Mark, "Sense Matter", The Center for Industrial Design, NorthCumbria University, On-line: http://www.cfid.co.uk/portfolio/research/pdf/senses_matter.pdf

6.1.2.1 Industrial Design Management

Industrial Design as any of the design methods and processes available for NPD needs to be well planed and managed. Also the need to locate and select the proper designer for a specific job is crucial. Before embarking into a industrial design project one should give a little bit of thought to the need of working with an industrial designer, the gains or potential benefits for such a partnership and the ways to plan such an engagement.

To pinpoint the value of such engagement one should consider the following.

- What are the customer requirements?
- What elements of the design are crucial to the success of the product?
- What skills are available and what do we need?
- What are the financial benefits?
- How do we compare to our competition?

To identify the type of industrial design involvement one should consider the following.

- How important are human factors or ser interface issues in the new product?
- How important is creativity and innovation?
- Is the work primarily styling?

Lastly to plan the engagement one should consider the following.

- What is the scope of the project?
- What form an initial brief on the engagement should have?

When all the above are answered i.e. the need for industrial design is established, the type of design involvement is identified, and the relationship is planed, then the selection criteria should be set. Their identification is crucial since they will be used later to evaluate the pros and cons of different possible suppliers. These criteria can differ from company to company and can include elements such as price, location, specific skills, IT and communication, track record and personality.

Often designers are selected based on word of mouth or previous experience. It can be very difficult to locate the right person with the right skills. Alternative approaches include location using design directories, web links, and local business links. If all fail one should seek out examples of products that one likes and contact the manufacturer to identify the industrial designer(s) involved.

As a rule one must select 5 suppliers and contact 3 of them asking them to respond to a short brief prepared with the involvement of all team members. All the members must agree on the form and contents of the brief. An effective brief must have the following.

- Exactly what is required from the industrial designer: all usability issues, potential form and feel and technical and quality aspects.
- All the critical constraints such as timescales, budget, resources, manufacturing process, scope of project and specific technical requirements.
- Some company information such as background, market information, user requirements (if any) and expected sales volume.

Depending on the responses the right supplier with the skills needed is selected.

The relationship between engineers and industrial designers becomes increasingly important. It is vital that all concepts are supported and are feasible and producible. Managing such relationship requires a joint appreciation of the following issues.

- Knowing who is responsible to deliver which aspects and when.
- Breaking the project into discrete phases.
- Having an agreed approach regarding management changes during the process.
- Identifying the system architect.
- Partitioning each task base on a understanding of interfaces between components.
- Identifying the commercial, technical and market risks.
- Ensuring IT compatibility and effective data transfer.
- Identifying the modes of informal and formal communication between members.

6.1.2.2 Industrial Design Activity Map

For someone to perform industrial design needs some kind of methodology and actions plan that will guide him through the whole process. Such a guide is the design map that follows. The map is basically a series of actions that one should take to be able successfully perform industrial design.

The main actions are four and each of them is split up depending if they are internal or external. Each of the internal or external actions is made up by smaller activities that are described bellow.

Figure 1: Diagram of the Design Map

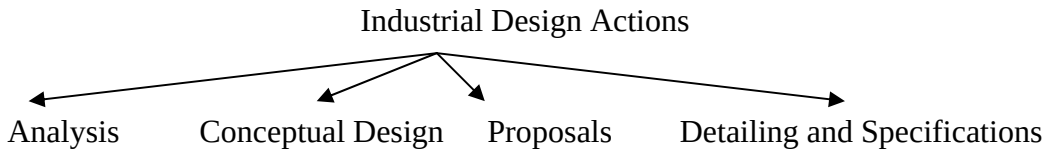


Table 1. Activities of Industrial Design Actions (Some activities are the same in different actions and may be repeated internally or externally depending on the action)

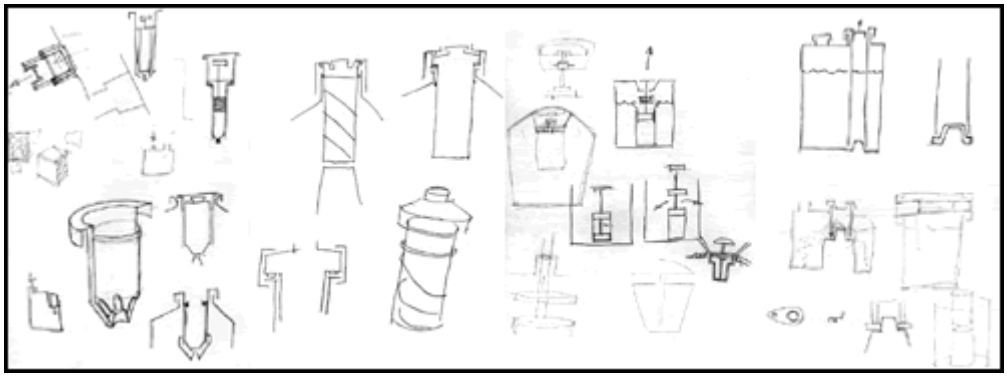
Activities	**Actions**			
	Analysis	**Conceptual design**	**Proposals**	**Detailing & Specification**
Internal	Sketch & Draw	Sketch & Draw	Sketch Model	Sketch & Draw
	Sketch Model	2D Technical Drawing	3D Digital Model (Constrained)	Sketch Model
	Prototype	3D Digital Model (Constrained)	3D Digital Model (Unconstrained)	2D Technical Drawing
		3D Digital Model (Unconstrained)		Prototype
External	Sketch & Draw	2D Technical Drawing	Sketch & Draw	Sketch Model
	2D Technical Drawing	3D Digital Model (Constrained)	Sketch Model	2D Technical Drawing
	3D Technical Drawing	3D Digital Model (Unconstrained)	2D Technical Drawing	3D Digital Model (Constrained)
	3D Digital Model (Constrained)	Prototype	Presentation	3D Digital Model (Unconstrained)
	3D Digital Model (Unconstrained)		Appearance Model	Prototype
	Prototype		Prototype	

6.1.2.2A Sketch & Draw

This activity is used to explore design issues. The activity by itself must be exploratory, quick and descriptive. Sketches are used to explore issues raised by the brief. Sketches may be used to establish in very approximate terms an outline of the issues posed by the brief, they enable us to

'shape' the problem and to understand it. Sketches are quick and loose and help to externalise thoughts. They can be used to communicate and think through ideas with oneself or with others in a team. They are often used in conjunction with words, written or spoken. They often serve as illustrations to early conversations or thinking processes and although potentially may not mean much to a 3rd party, often serve as markers for ideas, which can be returned to later.

Figure 1: Examples of sketch & draw activity results.



Source: "Sketch & Draw", The Center for Industrial Design, NorthCumbria University, On-line: http://www.cfid.com/portfolio/research/Nina/HTML-files/media-types/analysis-internal-sketch & draw.htm

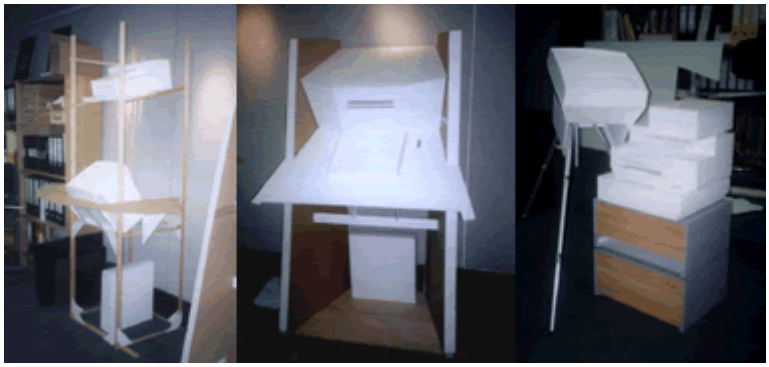
In the examples shown above sketches were used at a very early stage to establish the extent of the problem posed by the brief and to brainstorm some potential solutions to give confidence that the problem could be solved. In this case study this was done prior to the project proposal being written.

Source: The Center for Industrial Design, Northcumbria University, On-line **Source:** "Sketch & Draw", The Center for Industrial Design, NorthCumbria University, On-line: http://www.cfid.com/portfolio/research/Nina/HTML-files/media-types/analysis-internal-sketch & draw.htm

6.1.2.2B Sketch Models

Sketch models are used to explore scale, volume, proportion and spatial issues. Sketch models must be informative, exploratory and may take many forms: foam models, rough test rigs etc. In the analysis action they might be used to establish & test configuration options, explore volume and spatial issues. They are exploratory and as such they should always be moving in parallel with the thinking process, and therefore need to be relatively quick to create. Sketch models can be seen as a form of '3D sketching'. As with sketches they can assist personal thinking or be used as part of a team process. Early configurations and volume studies can also be carried out within a 3D modelling system which might be more accurate but has the disadvantage in that it cannot be touched, held or walked round. Sketch models are often not to scale and are often made in materials, which bear no resemblance to the final product.

Figure 1: Example of a sketch full-scale model.



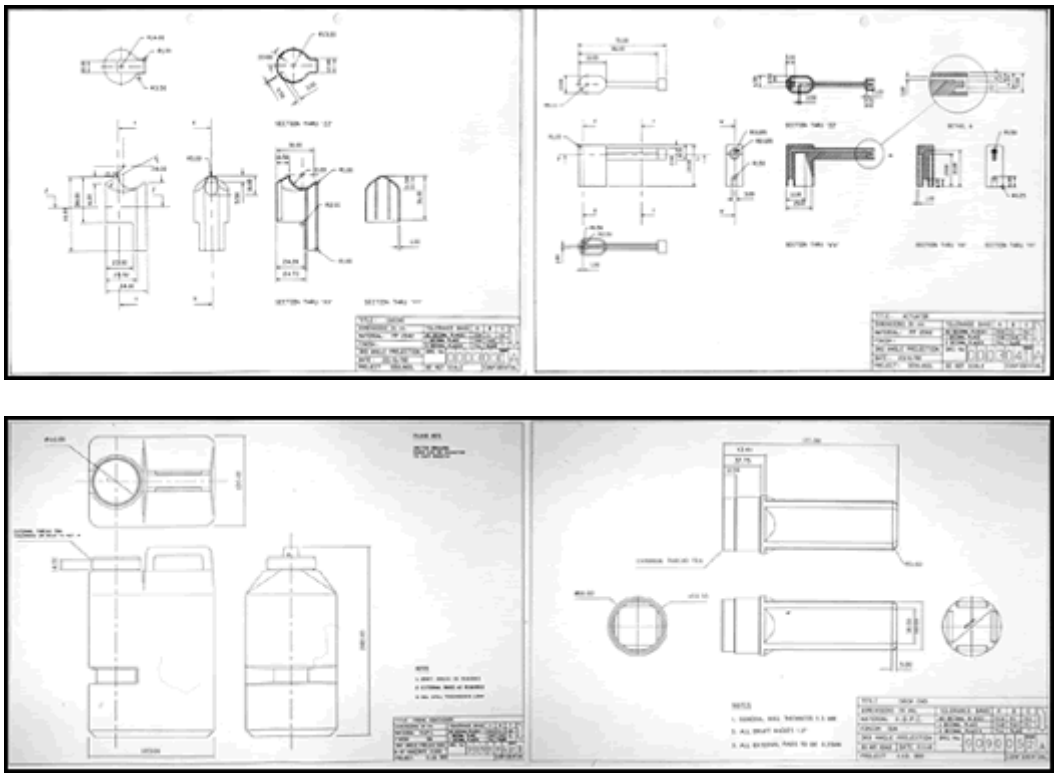
Source: The Center for Industrial Design, Northcumbria University, On-line Source: "Sketch Models", The Center for Industrial Design, NorthCumbria University, On-line: http://www.cfid.com/portfolio/research/Nina/HTML-files/media-types/analysis-internal-sketch models.htm

6.1.2.2C 2D Technical Drawing

These drawings are used to discuss manufacturing details and issues. They must be detailed, accurate, and informative and can be duplicated. Technical drawings, both hand drawn or digital are an extremely useful means of communicating to third parties when researching issues such as feasibility & cost. They can be used to describe a potential design in a way that can be understood by suppliers and can provide enough detail & information to enable them to make some form of considered feedback.

They are often used to obtain a range of castings, from ballpark to final. However, all 2D technical drawings suffer the same drawbacks, they are an impression of a 3D shape, and for their creation require a significant amount of skill in order to represent the 3D shape correctly. Further, they require interpretation by the person reading the drawing in order that the 3D shape can be. Earlier in the process this may not constitute a major problem, but if one is relying on a 2D specification for manufacture, then the success of the end result depends heavily on the skill of both the creator and the interpreter of the information. Although suffering the same drawbacks, digitally created 2D technical drawings (2D CAD) are much more flexible and useful than their hand drawn cousins. They can be edited and modified at will and can be printed as many times as needed. For the best possible accuracy they can also incorporate 2D snapshots of 3D data, enabling the addition of dimensions or notes, which can assist in the evaluation of the design or in the manufacturing process.

Figure 1: Examples of hand - made and digital 2D technical models.



Source: The Center for Industrial Design, Northcumbria University, On-line Source: "2D Technical Drawing", The Center for Industrial Design, NorthCumbria University, On-line: http://www.cfid.com/portfolio/research/Nina/HTML-files/media-types/analysis-external-techdraw-digi.htm

6.1.2.2D 3D Digital Model (Constrained)

3D digital models, both unconstrained and constrained, can be used to support the analysis process. They can be used to discuss design feasibility and costing issues with a range of suppliers. 3D models provide what might be called a '360 degree' view of the design, enabling interrogation of every modelled element. In comparison to 2D representations of the design, such as 2D technical drawings, they require no representation of the 3D shape by the creator, and no interpretation by the client or supplier. They are significantly superior in their ability to communicate the design and avoid ambiguity. Digital models can be viewed in a number of ways, on screen, where they can be moved around and interrogated, or snapshots can be taken and imported into a digital presentation or printed onto hard copy. Constrained digital models provide a complete '360 degree' view where all aspects of the design are communicated and can be interrogated, including the ability to carry out mould flow and other engineering analysis. This complete picture enables accurate assessment of design feasibility as well as costs.

Figure 1: 3D digital models example

Source: "3D Digital Model", The Center for Industrial Design, NorthCumbria University, On-line: http://www.cfid.com/portfolio/research/Nina/HTML-files/media-types/analysis-external_s_digimodel.htm

Constrained models can be used to support the detailing and specification process. It is during this stage of the process that they are at their most useful. Constrained models are ideal for this action in that they have access to dimensioning, draft and FEA tools. Further, constrained models have direct access to 2D drawing output, what is known here as a 3D technical drawing. Constrained 3D digital models can be used to fully define the design and detailing of all aspects of the product, including internal and external detailing. By the time this action is undertaken the designer should have a very good idea as to the general configuration and form language of the design, it is therefore ideal that 3D should be employed at this stage to create the model, which will be used to define all aspects of the design.

Figure 2: Constrained 3D digital models example

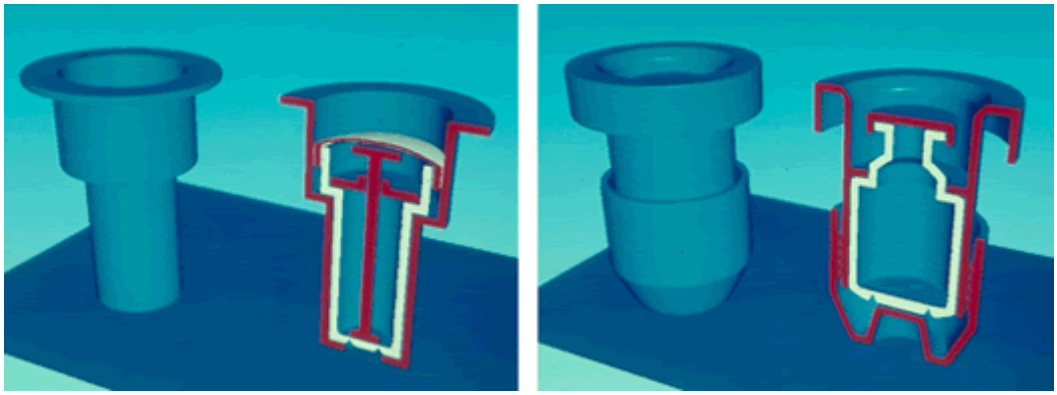
Source: "3D Digital Model", The Center for Industrial Design, NorthCumbria University, On-line: http://www.cfid.com/portfolio/research/Nina/HTML-files/media-types/analysis-external_s_digimodel.htm

6.1.2.2E 3D Digital Model (Unconstrained)

3D unconstrained digital models can be used to support the analysis process. They can be used to discuss design feasibility and costing issues with a range of suppliers. 3D models provide what might be called a '360 degree' view of the design, enabling interrogation of every modelled element. In comparison to 2D representations of the design, such as 2D technical drawings, they require no representation of the 3D shape by the creator, and no interpretation by the client or supplier. They are significantly superior in their ability to communicate the design and avoid ambiguity. Digital models can be viewed in a number of ways, on screen, where they can be moved around and interrogated, or snapshots can be taken and imported into a digital presentation or printed onto hard copy. Unconstrained 3D digital models provide this '360 degree' view but cannot be interrogated to the same extent as a constrained model and therefore provide more in the way of visual information than hard data. By their very nature unconstrained models are not modelled to hard specifications and are therefore not as accurate as their constrained cousins. Unconstrained models can also be used to support the creation of rapid prototypes although often-additional work has to be done to the model to make it suitable.

They can also be used to support the conceptual design process. They are used much in the same way as a physical 3D sketch model to provide the feedback necessary in order to progress the design. Compared to a sketch model they are significantly superior in their ability to communicate the design and avoid ambiguity. Unconstrained models are more likely to be used earlier in the process due to their more 'sketchy' nature, 3D form, which may be difficult to visualise in sketches or foam, can be created digitally providing a high level of feedback. The drawbacks are that digital models take longer to create than a sketch or a sketch model, using a digital model too early in the process may cause the designer to 'lock in' the design too early, perhaps being reluctant to change the model radically once it has been created. Further, it has been found that problems can arise if designers attempt to 'design' on CAD, digital modelling tools are such that progress is much better if the designer knows, even approximately, what the design will be like before he/she sits down in front of the screen. This is less so with unconstrained models, which have the opportunity to be 'pushed and pulled' into shape, however it is still advisable to have an approximate idea of the design before sitting down at a blank screen.

Figure 1: Unconstrained 3D digital model example

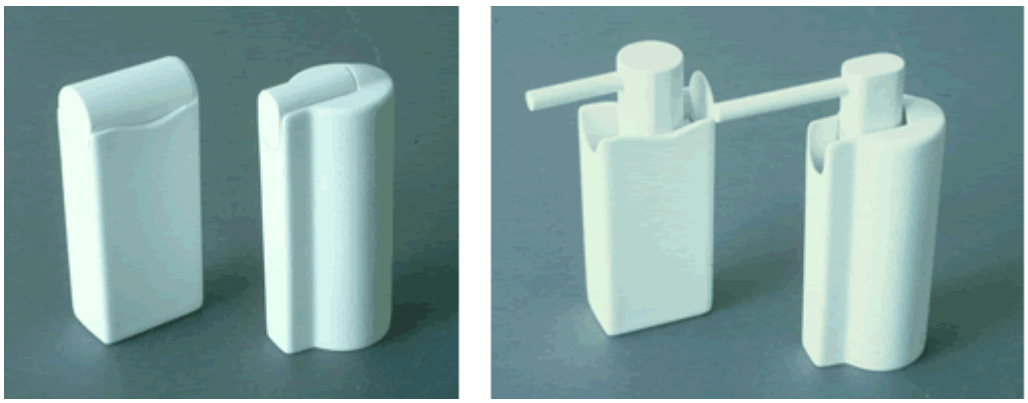


Source: "3D Digital Model (Unconstrained)", The Center for Industrial Design, NorthCumbria University, On-line: http://www.cfid.com/portfolio/research/Nina/HTML-files/media-types/analysis-internal_ns_digimodel.htm

6.1.2.2F Appearance Model

Appearance models might be created in order to present the concept to third parties outside the immediate client/supplier sphere. Such models might be used in market research, or as part of a company review process. The response to them may shape project funding or continuation decisions. Appearance model are just that however, unlike prototypes, they would not have any 'working' aspects; they would merely be 3D 'pictures' of the proposed design. Despite having little or no functionality, appearance models would look like real things and are therefore able to inspire strong emotional reactions in viewers.

Figure 1: Example of appearance models



Source: "3D Digital Model", The Center for Industrial Design, NorthCumbria University, On-line: http://www.cfid.com/portfolio/research/Nina/HTML-files/media-types/proposal-ex-external_app_model_trad.htm

Digital appearance models differ from non-digital in that the main shape for the model is created directly from data provided by the 3D digital model. The digital model provides data to drive machinery such as a CNC milling machine. Non-digital models can be created in number of ways, perhaps via the supply of 2D technical drawings, supported by a 3D sketch model. The key difference is that the digitally driven model is accurate to the 3D digital model, whereas the non-digital model requires interpretation by the model maker of the information provided.

Source: "3D Digital Model", The Center for Industrial Design, NorthCumbria University, On-line: http://www.cfid.com/portfolio/research/Nina/HTML-files/media-types/proposal-ex-external_app_model_trad.htm

6.1.2.2G Computer Visualisation

The pre-existence of 3D digital models supports the creation of computer visualisations and/or animations to support presentation of the concept outside of the immediate external client/supplier audience. These more glamorous representations of the proposed design might be used for market research, or perhaps to communicate the design to client peers or affiliates in order to maintain confidence or just to communicate as part of a company wide project review process. Such forms of communication are glamorous and can be informative and exciting, but are more of a surface view of the product. They let the viewer see what the presenter wants them to see. Animations in particular are highly time consuming and should not be undertaken lightly.

Figure 1: Example of a computer visualisation model

Source: The Center for Industrial Design, Northcumbria University, On-line Source: "Computer Visualisation", The Center for Industrial Design, NorthCumbria University, On-line: http://www.cfid.com/portfolio/research/Nina/HTML-files/media-types/proposal-ex-external_comp_vis.htm

6.1.2.2H Presentation - Illustration

Presentation illustrations, created digitally or non-digitally, can be used to support design presentations. The Non Digital versions are a development of sketch & draw and are a richer method of communicating design intent. In some instances they try to suggest what the design might look like once made, this is usually done via a process of rendering, using tools such as markers or coloured pencils. They help add life to a design concept, giving it an extra dimension, perhaps an element of 3D-ness. They are less coherent than a 3D representation; this may be appropriate in some situations where only a gut reaction to a range of ideas is required. Often, if less detail is available, viewers find it easier to focus on the idea as a whole, rather than on the way the design looks. Although they might be seen to hold less value than a 3D representation of a design, they are much quicker to create potentially allowing the creation of a much larger range of concepts. They can be used to make the product look very glamorous, and it is easy to hide the fact that design issues have not been resolved behind this glamour.

Figure 1: Example of model presentation

Source: The Center for Industrial Design, Northcumbria University, On-line Source: "Presentation - Illustration", The Center for Industrial Design, NorthCumbria University, On-line: http://www.cfid.com/portfolio/research/Nina/HTML-files/media-types/proposal-external_presillus_trad.htm

6.1.2.2I Prototype

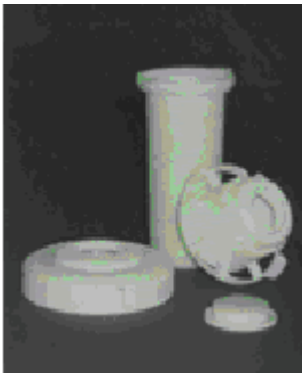
Prototypes can be used to develop the design detailing and specification either as a personal experimentation process or as part of a team. Hand built prototypes invite continual modification until the design is acceptable. At this stage realistic materials should be used to reduce inaccuracies as much as possible. Prototypes can be used to completely simulate the finished product, incorporating working components etc.

Figure 1: Example of prototypes

Source: "Prototype", The Center for Industrial Design, NorthCumbria University, On-line: http://www.cfid.com/portfolio/research/Nina/HTML-files/media-types/proposal-external_prot_trad.htm

A prototype might exist as a support to the final specification, illustrating it and showing how the product should look and function. A digital prototype could illustrate form, fit & assembly issues as well as issues such as mechanistic behaviour. A digital prototype requires the pre-existence of a digital model.

Figure 2: Example of a digital prototype

Source: "Prototype", The Center for Industrial Design, NorthCumbria University, On-line: http://www.cfid.com/portfolio/research/Nina/HTML-files/media-types/proposal-external_prot_trad.htm

6.1.2.3 Consultants - Experts

- Industrial Design & Construction (IDC) (http://www.idc-ch2m.com)

Industrial design and construction company based in the US, which supplies and facilitates planning, designing and construction of products for process intensive technology industries.

- Institute of Design of Ume University (http://www.dh.umu.se)

Institute of Design of Ume University was founded in 1989 and it is organized solely for the purpose of teaching industrial design. The institute is collaborating with the EU through the Mal1 Norra Norland Program.

- Sowden Design (http://www.sowdendesign.com/english/index.cfm)

Sowden Design is a company that designs and constructs computer peripherals and other electronics using 3D computer models, which are used for prototyping.

- Center for Industrial Design (http://www.cfid.co.uk/)

The Center for Industrial Design is a research led design consultancy, which functions as a commercial enterprise within the University of Nothcumbria at Newcastle, UK.

- Transform Design (http://www.transformdesign.com)

Transform Design is an industrial design firm servicing both industry and consumer oriented manufacturers since 1991. Transform Design services include all phases of bringing a product to a market, from analysis to manufacturing.

- Teams Design (http://www.teamsdesign.com)

Teams Design in an international industrial design consultant, which provides complete product design and development services.

- Creative Design (http://www.creative-design.co.uk)

Creative Design is an award winning product design consultant based in the UK.

6.1.2.4 References

- Cooper R, "The Design Agenda: A Guide to Successful Design Management", John Wiley & Sons, UK, 1995
- Kelley T, "The Art of Innovation", Harper Collins Business, London, 2001
- Thackara J, "Winners: How Today's Successful Companies Innovate by Design", Gower Publishing UK, 1997
- Ulrich & Eppinger, "Product Design and Development", McGraw Hill, USA, 2000
- Walsh, Roy, Bruce & Potter, "Winning by Design", Blackwell Business, UK, 1992

6.1.3 Lean Manufacturing

Lean manufacturing is a business tactic whose aim is to reduce waste in manufactured products and can be applied during the manufacturing process. Most product costs are assigned when a product is first designed. It is typical for engineers to assign or specify materials and manufacturing processes that are reliable but in most cases expensive. This tactic reduces the reliability risk but increases the manufacturing costs of a product. Instead of doing a lot of companies have adopted some kind of checklists that are designed to review product designs and cut manufacturing costs.

Techniques have been developed for all levels of product design namely system engineering, mechanical engineering, electrical engineering and software engineering. Also tactics such as the "Just In Time" technique are applied to reduce waste of the form of unused inventory of product components.

6.1.3.1 Electrical Engineering Level

At the electrical engineering level, lean manufacturing is the process of identifying the product components or processes that add cost and replace them or completely eliminate them. Usually what happens is that expensive mechanical processes are replaced with cheap electrical or software ones and expensive electrical or electronic components eliminated or replaced with cheaper ones.

An important factor in electronic and electrical engineering is the way tolerances are treated. Usually components have different tolerances and the small tolerances are found in expensive components. So a solution based on lean manufacturing is to replace these components with other ones of larger tolerances but in the same case the product functionality remain the same or close to the one achieved with the small tolerance components.

Another lean manufacturing solution that can be applied to the electrical engineering level is the integration of mechanical and electrical parts in such a way to reduce count of cables, connectors and other electro-mechanical material.

6.1.3.2 Mechanical Engineering Level

In the case of the mechanical engineering level, lean manufacturing is the process of reviewing the materials and processes to be used in product manufacturing. A review team made of an accountant, a product design engineer and a manufacturing engineer, should identify the materials and processes that add costs into manufacturing and try to eliminate or reduce them. For example the use of die casts or moulds instead of machining in the case of metal part production is a cost cutting solution.

The tooling costs and any production machinery costs are also estimated and alternative solutions should be identified by the review team. For example the reuse of machinery for completing different tasks can be a cost cutting solution.

In many cases it is crucial to identify materials that require less time to form or less time to be machined due to their characteristic properties. Again the review team should identify such possibilities.

6.1.3.3 System Engineering Level

At the system engineering level, product requirements must be reviewed with marketing and customer representatives to eliminate or reduce costly product requirements. Product requirements are assigned to the cheapest discipline. For example product adjustments and measurements may be moved to software rather than a electrical or mechanical solution that may be more expensive.

6.1.3.4 Just In Time (JIT)

The Just In Time (JIT) technique is a lean manufacturing tactic designed to reduce manufacturing costs by reducing and eventually eliminating the product parts or components in a company inventory. The idea behind the technique is to have enough product parts or components in inventory (in a warehouse) to achieve production of a specific number of product units. Usually this specific number being the number of ordered units by the customers.

This tactic or technique which, was first tried and developed by Toyota Motor Corporation, has the advantage of cutting costs by reducing or eliminating the stocked pilled unsold products or product parts. But in the same time has the risk of stopping or even slowing down the production line in the case of a bad or faulty part since there are usually no replacement parts as the product parts or components are just the ones required to have a certain number of product units. Also ones of the tactics main characteristics is the one of been able to plan an exact production timetable based on the available product orders and save money on labor.

6.1.4 CAD/CAM

Computer Aided Design-CAD is defined the use of information technology (IT) in the Design process. A CAD system consists of IT hardware (H/W), specialized software (S/W) (depending on the particular area of application) and peripherals, which in certain applications are quite specialized. The core of a CAD system is the S/W, which makes use of graphics for product representation; databases for storing the product model and drives the peripherals for product presentation. Its use does not change the nature of the design process but as the name states it aids the product designer. The designer is the main actor in the process, in all phases from problem identification to the implementation phase. The role of the CAD is in aiding him/her by providing:

- Accurately generated and easily modifiable graphical representation of the product. The user can nearly view the actual product on screen, make any modifications to it, and present his/her ideas on screen without any prototype, especially during the early stages of the design process.
- Perform complex design analysis in short time. Implementing Finite Elements Analysis methods the user can perform: Static, Dynamic and Natural Frequency analysis, Heat transfer analysis, Plastic analysis, Fluid flow analysis, Motion analysis, Tolerance analysis and Design optimization.
- Record and recall information with consistency and speed. In particular the use of Product Data Management (PDM) systems can store the whole design and processing history of a certain product, for future reuse and upgrade.

The technique initiated in the MIT from Ian Sutherland, when the first system the Sketchpad was created within the SAGE (Semi-Automatic Ground Environment) research project. The automotive and aerospace industries were the first users and the forerunners of development of CAD technology.

The first system was very expensive, the computer graphics technology was not so advanced at that time and using the system required specialized H/W and S/W, which was provided mainly by the CAD vendors. The first CAD systems were mainframe computer supported systems, while today the technology is for networked but stand alone operating workstations (UNIX or WINDOWS based systems). AUTODESK was the first vendor to offer a PC based CAD system the AUTOCAD (beginning of 1980). Today WINDOWS is the main operating system for CAD systems.

The first applications were for 2D Drafting and the systems were also capable of performing only 2D modelling. Even today 2D-drafting is still the main area of application (in terms of number of workplaces). Later, (mid-1980), following the progress in 3D modelling technology and the growth in the IT H/W, 3D modelling systems are becoming very popular. 3D modelling was at the beginning wire frame based. Aerospace and automotive industries were using surface modelling systems for exact representation of the body of the product. At the same time solid modelling was recognized as the only system, which could provide an unambiguous representation of the product, but it was lacking adequate support for complex part representations.

Today we are experiencing a merge of solid and surface modelling technology. Most solid modelling systems are capable of modelling most of industrial products. Systems sold today (especially for mechanical applications, which are the majority of systems sold world-wide) are characterized as NURBS (Non Uniform Rational B-Sline) based systems, employing solid modelling technology, and they are parametric and feature based systems.

The use of CAD systems has also been expanded to all industrial sectors, such AEC, Electronics, Textiles, Packaging, Clothing, Leather and Shoe, etc. Today, numerous CAD systems are offered by several vendors, in various countries.

Source: Computer Aided Design - CAD, by Dr N. Bilalis, Technical University of Crete, On-line at http://www.urenio.org under the heading Innovation Reports.

6.1.4.1 References

* Bilalis N. "Computer Aided Design - CAD" (http://www.urenio.org/rsi.htm), Urenio, Technical University of Crete

6.1.5 Re-engineering

Product development practices can create many opportunities to reengineer and improve the process as a whole and reduce development time. Whether a product is developed in an R&D environment or not, it is very easy to improve the development process by perceiving problems, brainstorming opportunities, analyzing and redesigning.

To reengineer the development process one needs to fully understand the development process itself since the development of a new product can redefine a company's development process. Also benchmarking of the process can identify any changes and pinpoint improvement opportunities. Brainstorming can be also used to look for new improvement opportunities. In either case, knowledgeable personnel, to the appropriate level of management, must present all opportunities.

To be effective, any action that results to the improvement of the way that people work and subsequently the way business is done, leads to better processes and practices. In reengineering these actions must at all times lead to evolutionary change, which can stimulate morale and imagination (hence innovation) and can create the opportunities for the appearance of creative ways for dealing with adversary and competitive challenges.

In many cases as companies fight competition and severe economic situation; they tend to find solutions in extreme actions such as downsizing. This is a very good short-term solution but a very

poor long term one. By reengineering the business processes of a company, especially its product development practices, the company can benefit a great deal in the long term. Reengineering can mobilize employee commitment and imaginative cooperation and hence its product innovative development ability and not only that.

6.1.5.1 Case Studies - Examples

A hypothetical government agency charges $10 per employee paycheck issued due to layers upon layers of bureaucracy. By comparison a private sector commercial services agency with the same number of employees charges only $1,5. The government agency management decided to bring the $10 figure down to the one of the private sector agency by reengineering its payroll processes. To accomplish this, management asked all employees to write down workflow diagrams that showed who does what, how and when. When these diagrams were entered into a computer for data analysis, it became apparent that the charges were that high because the paycheck had to go through typically, the controller, then the personnel department, then the regional processing center and then the auditors.

Next the management made out a diagram showing how much money would have been saved if say the controller or the regional processing center or the personnel department were removed from the chain. By removing one of them and by reengineering the actual business practices that ordinarily take place in the remaining elements of the chain, so that to be more effective, the charges were reduced to those of the private sector agency.

6.1.5.2 Software Tools

http://www.semdesigns.com/Products/DMS/DMSToolkit.html

Semantic designs Inc is a company that has developed software package called **DMS Software Reengineering Toolkit**. The DMS Software Reengineering Toolkit is a set of tools for automating customized source program analysis and modification of large scale software systems and therefore reengineer the whole systems.

6.1.5.3 Consultants - Experts

Reengineering Forum (http://reengineer.org/)

The forum is an industry related association that encourages the combined industry - research review of the practice of reengineering of software, systems and business processes.

6.1.5.4 References

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6.1.6 Reverse Engineering

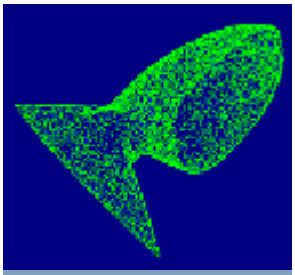
Reverse engineering is defined as the process of analysing a system or an object to identify its components and their inter-relationships and create representations of the system or the object in another form or at a higher level of abstraction. In the case of product development this is translated into the process in which an existing competitive product is analysed and documented so that its development process is understood. In this case the tricky part is to avoid copying it or stepping into copyright laws while doing so. This process can help companies that have no product development experiences and although have the resources to conduct product development do not know where and how to start.

The process is a practice that nowadays is often used by almost everyone in industry related companies such as computer hardware and software manufacturers, automobile industries, pharmaceutical firms etc. It provides a fairly cheap way in developing a new or a better offering of a product without the hassle of going through a complete development process. For example an automobile industry can purchase car of a competitive firm, disassemble it, examine the welds, seals and other components of the car for the purpose of enhancing their vehicles of similar components.

Source: Crow Kenneth, “A Methodology for Reverse Engineering”, On-line http://www.npd-solutions.com/remethod.html

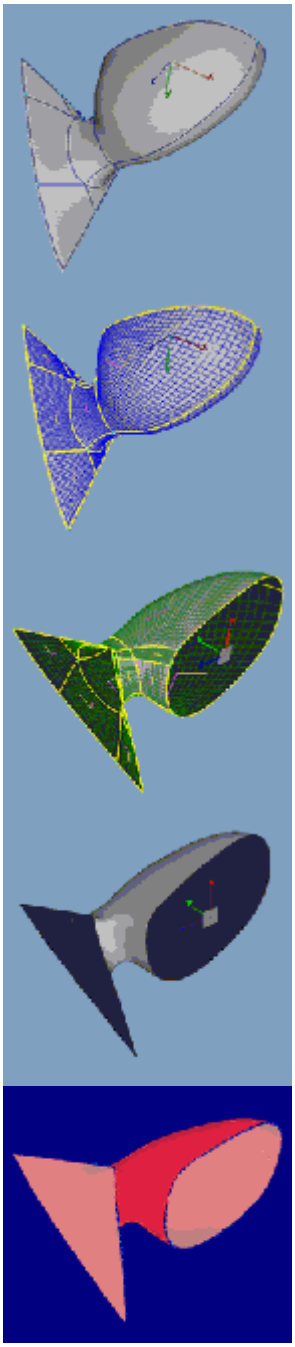
6.1.6.1 Reverse Engineering Methodology

A typical workflow in reverse engineering could involve scanning an object and recreating it. This process comes in a series of steps, which are discussed and illustrated bellow.



Step 1: A cloud of points is taken from scanned data using a digitizer such as a laser scanner, a computed tomography or faro arms.

Step 2: The cloud of points is converted to a polygonal model. The result is cleaned up, smoothed and sculptured to the required shape and accuracy.



Step 3: Curves are drawn or created on the mesh using automated tools such as feature detection tools or dynamic templates.

Step 4: A restructured spring mesh is created using semi-automatic tools.

Step 5: NURBS surfaces are fitted using surface fitting and editing tools.

Step 6: The final resulting NURBS surface, which satisfies accuracy and smoothness requirements, is exported to a CAD package for generating toll paths for machining.

Step 7: The part is manufactured and then analyzed for physical, thermal, electric or other properties.

Source: Crow Kenneth, "A Methodology for Reverse Engineering", On-line http://www.npd-solutions.com/remethod.html

6.1.6.2 Major Applications

6.1.6.2A Reverse Engineering of Business

Reverse engineering is not used only in cases of products or product components. It can also be used in the case of a business. The most common application of business reverse engineering is competitor product analysis. Reverse engineering can be used to analyse how a competitor product

works, what it does, who manufactures it, what kind of components consists of, how much does it cost to be produced, what kind of patents protects it etc.

Value engineering is a related activity which involves the deconstruction and the analysis of products and whose objective is to find opportunities for cost cutting.

6.1.6.2B Reverse Engineering of Electronic Components

Reverse engineering of electronic components is very much used nowadays since manufacturers of new electronic products need to solve interoperability problems. This means that new electronic components or new electronic in nature products need to be compatible with others so that information and services can be exchanged between them directly and satisfactory. Reverse engineering is used for competitive or otherwise electronic equipment functionality analysis so that a new product can be 100% compatible with them.

Coordinate - Measuring Machines (CMM) is one of the reverse engineering techniques that are used for electronic equipment. CMM can be used to digitize a circuit and the information to be used in computer-aided modelling. Another new and improved technique is laser scanning. The technique uses a laser beam o scan across the surface of components of any shape and display the results in real time in a computer screen.

6.1.6.2C Reverse Engineering of Software

Reverse engineering is applied to software in a big way. One of the most famous cases of reverse engineering of software is the case of the first non-IBM implementation of BIOS. In the US the "Digital Millennium Copyright Act" exempts from the circumvention ban some acts of reverse engineering aimed at interoperability of file formats and protocols and judges in key cases have ignored the law since it is possible to be acceptable to circumvent restrictions for use but not for access.

A typical example of software reverse engineering is the "Samba Software". The software allows systems that are not using or running Microsoft Windows to share files with systems that are. The Samba project had to reverse engineer the way Windows file shared worked which was unpublished and restricted Microsoft Corp information, so that a computer that did not use windows could emulate the procedure.

Reverse engineering of software can be accomplished by various methods. The two main ones is analysis through observation of information exchange and decompilation or disassembly using a disassmbler.

6.1.6.3 Case Studies - Examples

Reverse Engineering Case Study

Although the use of reverse engineering as means to duplicate or copy a software program constitutes a copyright violation and it is illegal, an example of how can be done is very useful in understanding the process and act as a case study of reverse engineering use.

Software reverse engineering involves in reversing a program's machine code (the binary string of 0's and 1's that are send to the processor) back into the source code that it was written in, using programming language commands. To do this, in the case of a complicated program, someone can use for example a hexadecimal dumper, which prints or displays the binary numbers of a program in hexadecimal format (which is easier to read). Knowing the hex words that make up the processor instructions, as well as the instructions length, a reverse engineer can identify certain portions of the program and see how it works. Also besides the dumper, a disassembler can be used to read the binary code and transform it into text displaying each executable command. A disassembler usually cannot tell the difference between an executable instruction and data send to the processor. So in this case the reverse engineer can use a debugger that does exactly that. So in any case using different tools a software program can be analyzed to the point that it is understood completely and can be copied or its source code altered to create a new software product through reverse engineering.

6.1.6.4 Consultants - Experts

- Future Technology Systems Consultancy (http://www.fts.gr/fts/ftsprduk.htm), Greece
- Industrial Center, Hong Kong Polytechnic University (http://www.ic.polyu.edu.hk/services/consultancy.htm)

- Liveware Software Engineering, Reverse Engineering Services (http://www.liveware.com/english/services/reengineering.htm)

- Team Engineering (http://www.team-eng.com/services/consultancy.html)

6.1.6.5 References

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6.1.7 Major Manufacturing Issues

6.1.7.1 Bill of Material (BOM)

A bill of material is a formally structured list for an object (semi-finished or finished product), which lists all the component parts of the object with the name, reference number, quantity, and unit of measure of each component. A bill of material can only refer to a quantity greater than or equal to one of an object. It is a product data structure, which captures the end products, its assemblies, their quantities and relationships.

There are usually two kinds of bills of materials needed for a product: engineering and manufacturing BOM. The engineering BOM normally lists items according to their relationships with parent product as represented on assembly drawings. But this may not be sufficient to show the grouping of parts at each stage of the production process nor include all of the data needed to support manufacturing or procurement. These requirements may force the arrangement of the product structure to be different in order to assure manufacturability. Thus, engineering and manufacturing will usually have different valid views for the same product.

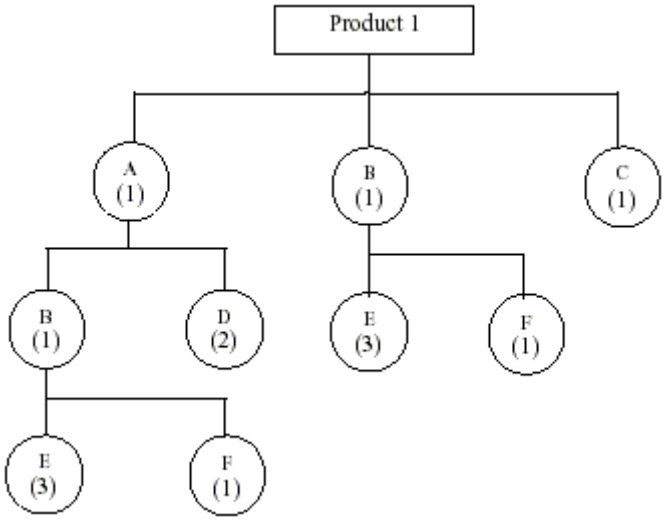
Manufacturing Requirements Planning (MRP) systems typically rely on a Bill of Materials (BOM) and the product structure for their information. In theory, the BOM can and should be produced automatically by the CAD system but in practice there is usually human intervention or even re-entry. The main reasons are: The difficulty of tracking changes to the BOM (product structure) and affectivity dates and transferring this data back to the design system. Many changes, such as different suppliers for fasteners, do not affect the design form, fit and function and are therefore only made and stored in the manufacturing systems. The need in manufacturing to view the product structure differently. It is often necessary to batch similar components from different products together for mass production or efficient purchasing.

Product Data Management (PDM) technology enables changes to be tracked and implemented through the design and engineering change process and then passed over to the MRP system when approved. Therefore PDM systems use BOM to represent configuration management of the product.

A Bill of Materials is a product data structure, which captures the end products, its assemblies, their quantities and relationships. The structure of a part's list determines the accessibility of the part's information by various departments in a company. It also helps to determine the level of burden put on the computational device in searching for product information. In many companies the BOM is structured for the convenience of individual departments. This, however, engenders problems in other departments.

In Figure 1, a product named Product 1 is shown graphically with the summarized products structure and the number of all items that are needed to make the parent products are enclosed in brackets.

Figure 1: Graphical Representation of Product 1 Structure



Source: Crow Kenneth, "Product structure and Bills of Material", DRM Associates, On-line http://www.npd-solutions.com/bom.html

Table 1 contains a bill of materials for Product 1 in which the total usage of each item is collected into a single list for the product. This kind of list is convenient for the master production schedule but results in the duplication assemblies. This implies that each product bill that uses assembly must be changed whenever there is a change in assembly. Furthermore, since lead times of intermediate assemblies cannot be determined, parts are ordered too early the first time they are encountered in the product structure.

Table 1: BOM for Product 1.

Part	Qty
A	1
B	2
C	1
D	2
E	6
F	2

Source: Crow Kenneth, "Product structure and Bills of Material", DRM Associates, On-line http://www.npd-solutions.com/bom.html

Other arrangements used in arranging the bill of materials is by indenting the product data as shown in Table 2. One disadvantage of this method is that all components of an assembly are repeated each time the assembly is used, resulting in massive duplication of data.

Table 2: Intended BOM

Product 1	Qty
A	1
B	1
E	3
F	1
D	2
B	1
E	3
F	1
C	1

Source: Crow Kenneth, "Product structure and Bills of Material", DRM Associates, On-line http://www.npd-solutions.com/bom.html

One solution to the duplication problem is by holding each assembly only once in 'single level' bill of materials as shown in Table 3. In this approach it identifies only the components used by one level and a required subassembly. This means that engineering changes can be made in only one place.

Table 3: Single-level bill of materials

Level 1

Part/Product 1	Qty	Pointer to level
A	1	A
B	2	B
C	1	

Level 2

Part/A	Qty	Pointer to
B	1	B
D	2	

Level 3

Part/B	Qty	Pointer to
E	3	
F	1	

Source: Crow Kenneth, "Product structure and Bills of Material", DRM Associates, On-line http://www.npd-solutions.com/bom.html

'Where used' lists give an easy overview of the products where a given material is contained. This happens by displaying of all BOM's, which contain this component.
Below is given the typical information, which can be found in a bill of materials:

Product or Higher-Level Assembly

- Product/Assembly Item Number
- Product/Assembly Name
- Product/Assembly Description
- Unit of Measure
- Revision Level

Each Component/Item

- Item Number
- Item Name

- Item Description
- Revision Level
- Unit of Measure
- Quantity per (each higher level assembly)
- Effectivity (date in and date out or serial number in and serial number out)

Source: DRM Associates (http://www.npd-solutions.com/bom.html)

6.1.7.2 Mass production

Mass production is the process of manufacturing large amounts of standardized products is a production line. The process permits very high rates of production per person and so it provides very inexpensive products. The aim of the process is the reduction of non-productive effort of any kind.

In craft production a single person must get all the necessary parts and assemble them to produce a product with the help of all kind of tools which are used many times. In mass production each worker repeats one or few related tasks and uses the same tool to perform almost identical operations in a stream of products. The tool and the parts required are always there and no time is spent getting them or finding them.

Mass production systems are usually organized in assembly lines. A factory may have more than one assembly lines in the cases of complex products. A diagram of typical mass production factory looks like the skeleton of a fish. Different sub-assembly lines are used to produce different parts of a product and all finished parts are joint together at the end.

Nowadays managers choose which part or which product to put in a assembly line based on the return of investment (ROI) that a specific assembly line can produce. Assembly lines that are considered to have bad ROI are usually outsourced.

6.1.7.3 Producibility

Sometimes manufactured products have unnecessary precision, production operations or parts. Simple redesign of the product can eliminate these so that costs are lowered and manufacturability, reliability and profits are increased. There are a lot of examples in different industries where this is common practice.

Some Japanese disc brakes have parts with tolerances of three mm an easy to meet precision. This fact combined with some basic statistical process controls assures that less than one in a million will fail. Also many vehicle manufacturers have programs of reducing the number of types of fasteners in their product so that their inventory, tooling and assembly costs are reduced.

Another reducibility technique is "near net shape" forming. A forming process can eliminate many low precision machining or drilling steps. Also precision transfer stamping can produce hundreds of high quality parts fast from generic rolls of steel and aluminium. Die-casting is used to produce metal parts from aluminium or tin alloys. Plastic injection molding is a handy technique in cases where the part is supplemented with inserts of brass or steel.

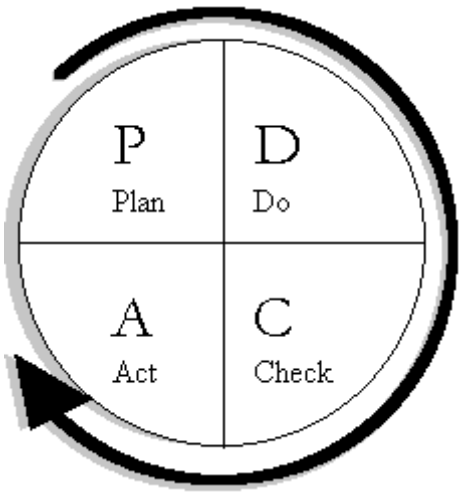
In the case of computer manufacturing, parts can be replaced with software that fits into a single lightweight low power memory part or micro-controller. In the electronics industry some PCB's (Printed Circuit Boards) contain parts that are leadless. This reduces the count of holes (Via) and clipping off the leads after soldering and therefore the cost of manufacturing.

6.1.7.4 Quality Assurance

Quality assurance covers all the activities from design, development, production, installation, servicing and documentation. But it also includes the management of raw materials, assemblies, products and product components; services related to production and all the inspection processes. That is why it is vary important to the product manufacturing process. One of the most widely used quality assurance tool is the Plan - Do - Check - Act (PDCA) cycle that is also known as the "Shewhart Cycle".

The PDCA cycle is really nothing more than a four-stage checklist that one must go through to get from "problem faced" to "problem solved". The cycle was originally developed by Walter Shewhart. He was a pioneer statistician who was working in the Bell laboratories in the 1930's in the US. The cycle can be graphically presented as shown bellow.

Figure 1: The PDCA Cycle.



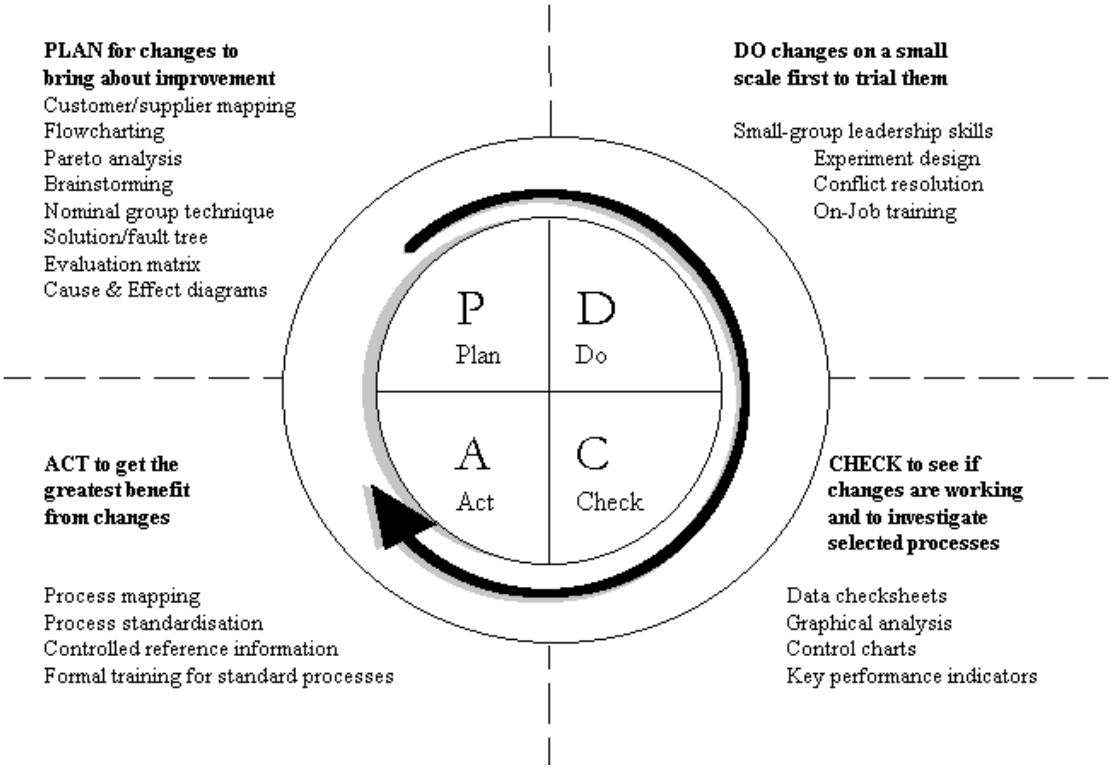
Source: HCI Professional Services, “The PDCA Cycle”, On-line http://www.hci.com.au/hcisite2/toolkit/pdcacycl.htm

Here is what one must do for each stage of the Cycle:

- Plan to improve your operations first by finding out what things are going wrong (that is identify the problems faced), and come up with ideas for solving these problems.
- Do changes designed to solve the problems on a small or experimental scale first. This minimises disruption to routine activity while testing whether the changes will work or not.
- Check whether the small scale or experimental changes are achieving the desired result or not. Also, continuously Check nominated key activities (regardless of any experimentation going on) to ensure that you know what the quality of the output is at all times to identify any new problems when they crop up.
- Act to implement changes on a larger scale if the experiment is successful. This means making the changes a routine part of your activity. Also Act to involve other persons (other departments, suppliers, or customers) affected by the changes and whose cooperation you need to implement them on a larger scale, or those who may simply benefit from what you have learned (you may, of course, already have involved these people in the Do or trial stage).

The next figure illustrates some of the tools or techniques that can be used. One must note that these are not to be strictly applied but one can use any or all of them.

Figure 2: Tools - Techniques That Can be Used in the PDCA Cycle



Source: HCI Professional Services, "The PDCA Cycle", On-line http://www.hci.com.au/hcisite2/toolkit/pdcacycl.htm

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6.1.7.5 Value Engineering

Value engineering is a branch of industrial - manufacturing engineering in which the output of a system is optimized. The optimization process consists of two components: the optimization of performance and the optimization of cost.

Usually cost and performance optimization within value engineering involves the reduction of product quality and thus the reduction of cost. But this should not to be the case. Cost optimization should reduce cost by eliminating wasteful practices. This can be done by several ways, which are discussed bellow.

- **Material substitutions.** Some materials that are used in a product can sometimes be substituted by less expensive ones. For example if a product has a life cycle expectancy of 10 years and it consists of materials with life expectancy of 15 or 20 years then these can be substituted since keeping them is a wasteful practice.
- **Process efficiency.** Sometimes manufacturing or production processes can be redesigned so that they are more efficient and therefore more cost effective. Process engineering can help a lot in this case.
- **Modularity.** Modules that are designed once and are used in many different products can reduce cost a great deal. By using the same modules in different products or applications reduces development costs, production costs and product complexity.
- **Energy efficiency.** A product can be designed to be energy efficient. This adds value to the product and although it does not necessarily reduces production costs may increase profits by increased sales. This is applied to heating and air-conditioning, transportation, and industrial equipment products.

Value engineering usually is performed in four stages:

1. **Information gathering stage.** This stage is really a product function analysis stage where all required product functions are determined.
2. **Alternatives generation stage.** In this stage all possible alternatives in respect to product functionality are identified.
3. **Analysis stage.** A thorough analysis of both the product functions and their alternatives is carried out during this stage.
4. **The decision stage.** Finally in this stage, decisions are made in respect to which functions can be altered and which can be replaced so that cost and performance are optimized.

NPD Stage 7: Product Commercialisation

If a company decides to go ahead with the commercialisation of a new product, it will face the largest costs to date. The company would have already spent much on product idea generation, product idea selection, product development, prototype development and product prototype testing and validation, but the amount of money that commercialisation requires is far more. The company will have to built, rent a large full-scale manufacture facility if it has none or outsource the manufacturing process, it will have to spend a bundle on promotion and advertising, it will have to decide upon and rent or contract a large distribution and delivery system, and it will have to take some very difficult and important decisions about the commercialisation process in general.

7.1 Tools & Solutions

Due to the nature of the NPD-NET Roadmap matters concerning manufacturing related issues are dealt in >Level 6< (1123). So in this Level the solution to the commercialising problem are related to all the marketing aspects of product distribution, product pricing and product promotion. These aspects include product advertising, product publicity and public relations, product pricing methodologies and product personal selling and selling promotion.

7.1.1 Marketing Plan

Marketing planning is a very complex and cross - functional process. It contains all the marketing activities and tasks that should reflect the company's strategies. Ideally all levels of an organization should understand such strategies so that each level can carry out its part. Since markets today are highly competitive, marketing strategies and marketing planning must have a big understanding of customer needs and market behaviour. Successful companies are those that have acute awareness of such issues and form their strategies accordingly.

The market plan is a document that focuses on bringing such strategies into life. It can be considered as a roadmap for performing marketing activities and tasks such as sales, advertising, promotion, and others having the successful product launch always in mind. Forming a market plan is a step-by-step process, which includes the following.

1. Understanding the strategy of one's company and taking steps for the establishment of links between company strategy and marketing planning.
2. Analyzing the environment within the company does business. This includes the market, the industry, the competitors and other issues.
3. Understanding the market segmentation so that the right customers can be targeted. These customers are the ones whose needs a new product will satisfy.
4. Knowing how and where to position the product so that its key features and values are shown to the target audience.
5. Forming the "marketing mix" which consists of a combination of activities which are used to bring the product into a market and sustaining it into this market for as long as possible. These activities include:
    - Deciding which products meet the needs of the pre - identified target customers.
    - Pricing those products so that their competitive value price is recognized by the market targets.

- Defining promotional programs to reach those target customers. Such programs include advertising and communications programs.
- Creating channels of distribution so that the new product or products are at the right time close to the target customers.

6. Determining the person or team that will bring the product into the market. That includes the sales team.
7. Launching product line extensions if this is considered necessary.
8. Training the sales team to competitive position the product.
9. Budgeting the marketing program so that all goals and strategies are satisfied.
10. Describing operational difficulties an dependencies of other organizations.

7.1.4 Distribution Channels

7.1.4.1 Distribution Definition and Considerations

The definition of a distribution channel was first given by Buclin in his book "Theory of Distribution Channel Structure" (1966). He wrote "Channel of distribution comprises a set of institutions which perform all of the activities utilized to move a product and its title from production to consumption". But in reality a distribution channel is not as simple as it is presented above. Many factors must be taken into consideration and a lot of things to be decided for a product to be moved from manufacture into the market.

First of all for successful distribution channel set up there are six basic decisions that must be made by the marketing team beforehand. These decisions are related to the questions that are given below.

- Use of direct or indirect channels?
- Use of single or multiple channels?
- What will be the cumulative length of the multiple channels if those are used?
- What types of intermediaries will be used?
- What will be the potential number of intermediaries if those are used?
- Which companies will be used so that to avoid "inter-channel" conflict?

When all the above questions are answered then the marketing team should select the distributor taking into account the following considerations.

- Market segment: the distributor must be familiar with the target consumer and segment.
- Changes during the product life cycle: different channels can be exploited at different points of the product's life cycle.
- Producer - distributor fit: there must be a match concerning policies, strategies and image between the producer and the distributor.
- Qualification assessment: the experience and the track record of all potential distributors must be established and assessed.
- Training and support: the amount of training and support that a distributor will require to have the job done must be taken into account.

7.1.4.2 Distribution Channel Strategy

A distribution channel strategy is influenced by many factors that fall into three main categories: market, producer and product. These factors influence the way a product distribution channel is set up and their consideration is crucial on the decisions that must be made by the marketing team to accomplish a successful product launch. All major factors are analyzed and discussed bellow.

Market factors. An important market factor is "buyer behaviour". This factor describes the way customers prefer to buy a product. For example do customers prefer to buy a product from a retailer, locally, via mail or perhaps from the Internet? Another one is "buyer needs" which describes what customers would like to have in regards to technical product assistance, product installation or product servicing. Both factors contain information that can be easily gathered during the early stages of NPD process by a market research when the product or the product concept is designed. The willingness and cost of channel intermediaries to the product are also a market factors. An intermediary could either charge a high commission that would be unacceptable by the producer or he could decide not to support a specific product if it requires a heavy investment.

Producer factors. Sometimes a producer will not have the resources that are necessary for all the distribution channel activities to be performed. If that is the case the use of agents or outside contractors is the only way that a product can reach a market. Also producers may not have the required customer approaching skills to sell their products. Channel intermediaries that invest heavily in customer relations are the only people that can create a competitive advantage for a given product. Another producer factor is the price and location of product sale. For example in the case when a producer sells via a retailer it is common that he loses control of the final product price due to retailer discounts, promotional offers.

Product factors. The way that products reach customers depend on what kind of products they are. For example complex equipment such as medical, aerospace or electronic components are sold directly to customers without the intervention of intermediaries, retailers or agents.

Another thing that influences the formation of a distribution channel strategy is distribution intensity. This can be intensive, selective or exclusive. Intensive distribution is focused on the complete saturation of the market by using all available methods to sell a product. Selective distribution on the other hand aims at the use of a limited number of outlets to sell a product. It can work very well when customers are willing to "shop-around". Finally exclusive distribution is an extreme form of selective distribution in which only one wholesaler, retailer or distributor in a specific geographical area is allowed to sell a particular product.

Source: Tutor2u Ltd, “Distribution Channel Strategy”, On-line http://www.tutor2u.net/business/marketing/distribution_channel_strategy.asp

7.1.4.3 Types of Distribution Channels

There are many types of distribution channels. The most important ones are wholesalers, agents, retailers, the Internet and overseas distributors and direct sales. A description of each is given bellow.

Wholesalers. These usually buy products from producers in large quantities and sell these to retailers. They take ownership or title of goods. Most of the times they provide storage facilities and sometimes take some of the product marketing responsibilities. The wholesaler provides minimum contact between the producer and the customer.

Agents. They are used mostly in international markets. They will typically secure orders for products and take commissions from the producer. Agents usually do not tie capital to goods but sometimes they can stockpile products in cases when products need to get into a market as soon as they are produced. They are very expensive to train and keeping them under control is a difficult task due to the distances involved. Also they are difficult to be motivated due to the nature of their payment.

Retailers. Retailers have a strong relationship with the customers. They will hold a lot of different products and brands in stock and they will usually offer credit or discounts to the customers. All products are promoted and merchandised by them. Also the retailers will have the final say on price.

The Internet. E-commerce is a distribution channel that is growing steadily in the past years. The Internet offers a large dispersed market to producers. Set up costs can be low and all the e-commerce technology is easily attainable. Also in recent years there is a shift in commerce and consumption habits that benefits distribution through the Internet.

Direct sales. Direct sales involve the supply of customers directly from the producer's factory. The marketing or sales in-house department looks after all contacts. Usually direct sales involve international sales and require sales personnel or office away from home base.

In some cases one of the above alternatives is sufficient by one's company to bring a new product into a market. But in other cases a combination of some or all of the above alternatives will bring the desired result.

Sources:

- Marketing Teacher, “Place, Distribution, Channel or Intermediary”, On-line http://www.marketingteacher.com/Lessons/lesson_place.htm
- ICT USA, “ICT Channels of Distribution”, On-line http://www.emich.edu/ict_usa/CHANNELS_OF_DISTRIBUTION.htm

7.1.5 Product Pricing

Pricing is one of the product commercialization components along with promotion and distribution. A well-chosen price for a product should focus on three things: achieve the financial goals of the business i.e. profitability, fit with the reality of the market and support a products positioning that is aligned with the other aspects of product commercialization.

Price can be influenced by the distribution channel, the type of promotion used for the product and the quality of the product. It can be high if manufacturing is expensive, distribution is exclusive and the product is heavily supported by advertising and promotional campaigns. A low product price can balance product characteristics such as low quality and light advertising. From the marketers point of view the best price is the one that it is very close to the maximum customers are willing to pay.

Product pricing can have different characteristics and involve different strategies. Some of the strategies that are used in product pricing are:

- "Premium Pricing" is a pricing strategy that involves pricing of a product at or near its possible range. Consumers will buy Premium Priced products because they believe that are of high quality (a high price is a sign of self worth) and they require best product performance.
- "Demand Pricing" is a pricing method that uses consumer demand as the central element.
- "Promotional Pricing" is a pricing strategy that sets price as the key element of product commercialization i.e. is used in conjunction with advertising and promotion to get the product quickly known.

7.1.5.1 Product Pricing Objectives

A pricing strategy must be always focused on specific pricing objectives or goals. For someone to set up a pricing strategy must first determine the pricing objectives. To do this one should consider the overall financial, marketing and economic objectives of the company, the objectives of the product, the consumer price elasticity and price points and the resources that are available. Some of the most common pricing objectives are given in the table bellow.

Table 1: Pricing Objectives

Maximize long –run profit
Maximize short-run profit
Increase sales volumes
Increase market share
Achieve the target of Return of Investment (ROI) set
Maintain price leadership
Maintain company growth
Discourage competitive entrances into the market
Match competitor prices
Create interest about the product
Create competitive advantage
Help promote the company
Help obtain and maintain distributor and sales personnel loyalty

7.1.5.2 Pricing Methods

7.1.5.2A Competitor Indexing

Competitor indexing is a pricing method that is used by marketers. It involves the use of the price of competitor products to set one's own product price. This strategy is typically used by companies, which belong to an industry with 2 or more dominant companies. It has the advantage of being easy to use and extensive marketing and statistical analysis are not required. But it has the disadvantage of being purely reactive. Typical pricing decisions based on this method are given bellow.

- Matching of competitor price.
- Setting price 5% above or bellow the competitor one.
- Setting price at a specific amount bellow or above the competitor one.
- Setting price within a range from the competitor one.

7.1.5.2B Cost-plus Pricing

Cost-plus pricing is a pricing method that is often used by companies because it is very easy to calculate product price with little information. There are several varieties of the method and the most common one is the one that uses the following formulae.

$$P = (AVC + FC\%) * (1 + MK\%)$$

Where P = price, AVC = average variable cost, FC% = percentage allocation of fixed costs, MK% = percentage markup. For example if variable costs are €30, the allocation to cover fixed costs is €10, and a 50% markup is needed then one should charge €60 for the product.

To make things even easier and simpler, some retailers ignore fixed costs and just use the price that they have paid to their suppliers as the cost term of the equation. This way they "insert" the fixed cost into the markup percentage. To simplify things even more sometimes a percentage for the markup is not used. Instead a fixed amount is set by the head office to make it easy to retailers and store managers to set price for products.

Cost-plus pricing is easy to calculate, it requires minimum amount of information, it is easy to administer and has the ability to stabilize markets (it is not affected by factors such as demand variations, competitive forces and ethical advantages). In the same time cost-plus pricing ignores the role of the customers, ignores the role of the competitors, uses historical accounting costs rather than real-time ones, uses a standard output level to allocate fixed costs, ignores the opportunity costs and ignores possible incremental costs.

For more information please see: http://en.wikipedia.org/wiki/Wikipedia:Copyrights

7.1.5.2C Price Skimming

Price skimming is a pricing method in which a marketer set a high price for the product at first and then gradually lowers this price over a period of time. This pricing strategy allows the company to recover production and other product costs quickly before competition steps using the high product price in and then profit and work against the competition by lowering the product price. The strategy is often referred as "riding down the demand curve". This is because marketers try to lower product price following the decrease in consumer demand as time goes by and competition steps into the market.

There are some drawbacks of the strategy that must be considered before embarking into price skimming. Firstly the method encourages the introduction of competitors that see an opportunity and step in very quickly. This often has the result of using the pricing method for defensive purposes and not for goal achieving ones. Secondly negative publicity can result from fast price lowering. This is because some early consumers or customers will feel ripped-off since they would have paid a high price for a product that will have a low price in a short period of time. Thirdly cost may not be recovered and the objective of the price strategy not achieved. And last but not least lowering the price of a product may have legal implications depending on the laws that apply to a specific market.

7.1.5.2D Target Rate of Return Pricing

Target rate of return pricing is a pricing method used almost only by market leaders or companies that have product monopolies. The idea behind the method is to start-off with a rate of return objective, for example 5% of invested capital or 10% of sales revenue, and then arrange the price structure so that to achieve the target rates of return. The idea and the pricing method are best illustrated using the simple example that is given bellow.

- A company invests €100 million to produce and market designer woman's shoes.
- They estimate that the European demand is such that they can sell 2 million shoes per year.
- From preliminary production cost evaluation they know that each pair of shoes will cost €50. So the annual production cost will be €100 million.
- Management decides that a 20% return of investment is needed. So the return of investment must be €20 million.
- So the price for a pair of woman's designer shoes must be set to €60.

A typical but often unseen consequence of this pricing method is the fact that price should be altered often to match consumer demand. Since a fixed rate of return of investment is used in the price calculations, as demand falls, price must be increased to keep the desired rate. As demand falls the profit margin can be decreased to keep the price steady but this will decrease the profit

objectives set by the company. This is the reason why this pricing method is used only by market leaders and product monopolists. Only they are in the position to change rates of ROI or profit margins without much effect for their businesses.

7.1.6 Product Promotion

Product promotion involves the disseminating of information about the product. It consists of four subcategories: advertising, personal selling, sales promotion and publicity and public relations. These four subcategories create the promotional mix or the promotional plan of a product. The promotional plan has to do with how much attention one must pay to each of the four promotional subcategories and includes a set of objectives, which are given bellow.

- Sales increase.
- New product acceptance.
- Creation of brand.
- Product positioning.
- Competitive retaliations if required.
- Creation of a company image.

7.1.6.1 Advertising

In the early years of mankind and until printing was discovered advertising only existed in the form of word-of-mouth. As printing was developed in the 15th and 16th century the first steps towards modern advertising were taken. In the 17th century advertisements started to appear in weekly newspapers in England and a century later advertising had become a popular and common thing. As the economy grew and mankind entered the industrial age in the 19th century advertising grew as well. The first advertising agency was created in 1843 in Philadelphia by Volney Palmer and this agency and the ones that followed were just brokers for space in newspapers. Only in the 20th century advertising agencies started to take over the responsibility of the advertisement content as well.

From the early 20th century until now the purpose of advertising was to stimulate the consumer demand for a product, service or idea. The way this is achieved is by creating a brand franchise for a product. A brand franchise is created by the ability of the product to draw buyers. This ability is established in small or large degree depending on the product and the market. There are many advertising methods and techniques available which are presented and discussed in a separate section.

7.1.6.1A Advertising Channels

Brochures or flyers. Nowadays one of the most common methods of advertising is the use of brochures or flyers. Brochures can contain a great deal of information if they are well designed and written. Production of brochures can be done either in-house by using some kind of desk - top publishing or word processor software or they can be outsourced using an advertising agency. In the case of in-house production a attractive tri-fold brochure can be made by using a 8.5-inch by 11-inch sheet folded in thirds.

Direct mail. Direct mail can be used if one needs to convey product information directly to his customers. Direct mail can be customized so that the material sent is focused on customer specific needs and wants. Addresses can be collected either from customers by asking them to fill out information cards when they purchase a product or by collecting customer addresses from checks or invoices. A direct mail list must be kept updated. An easy way for someone to do this is to notice all returning mail.

Email messages. Emails can be a very easy way of informing people about your business. For this to be done a signature line can be inserted to every outgoing mail. One should note that this is much appreciated and noted by the recipients. One should be careful about inserting advertisements into outgoing mails since nowadays this can be perceived as Spam.

Magazines. Magazines advertisements can be very expensive but they can get your message out in a very powerful way. One should be careful to choose magazines that address issue in specific industries that interest you and your customers. A short article about one's business can be an alternative to an advertisement and can provide more information to potential customers. One way of keeping the cost at a low level is to contact a magazine reporter and arrange for a short interview. Most of the times reporters are looking for new stories or sources and do not charge for their services.

Newsletters. Newsletters can be an inexpensive way of advertising one's business or products. Unlike emails customers usually sign up for these when visiting a business website. The best way to go about introducing newsletters is to hire a consultant for the initial design and layout and then use the in-house Webmaster for web insertion or Internet set-up.

Newspapers (major or neighbourhood). One can get his/hers business known to the public using the newspapers by placing ads, writing a letter to the editor or working with a reporter to get a story written about the business. Advertising can get very expensive especially in the case of the major (large circulation) newspapers. Newspapers can sometimes provide advice about what and how to advertise. For small or medium size companies the best way of reaching the public is local or neighbourhood newspapers that are closest to the target customer interests.

Posters and bulletin boards. Posters can be a very powerful way of advertising when placed in places that the public can notice them easily. The best places to post advertisements are places that customers frequently use such as buses, the metro, by the road etc. One should make sure that advertisements in posters or bulletin boards contain vivid colors so that a customer's eye is easily attracted to.

Radio announcements or advertisements. One of the main advantages of radio ads is that they are cheaper than the television ones and reach almost the same audience in respect to size. Timing

is very important factor concerning radio ads. These should be placed at times when customers can listen to the radio such as in the morning or afternoon rush hour when they go or return from work.

Television advertisements. Most companies do not consider television ads at all due to their high cost. But nowadays, new television networks or station emerge at a very fast rate and competition can sometimes drop prices. So a company can place a television ad at a relative cheap rate. One should note that television ads are priced depending on their length, the time of showing and the number of ads per month or week or day.

Web pages. Nowadays advertising in the World Wide Web is commonplace for most businesses. Using the web for advertising requires some expertise, equipment and some kind of software so that ads can be designed, written and placed under a domain name. Also maintenance is required so that the advertisements are kept up to date in respect to new products and services. In the case that web advertisements are linked to some kind of ?-commerce then things can be complicated in terms of extensive functions and graphics and so a consultant or a web designer may be required.

7.1.6.1B Ways to get Free Advertising

Promotion and advertising can be a heavy expense for a business that either it is new and wants to be known in a market or has a new product that is going to be launched into a market. In the case of a small or tight budget, such as the budgets of typical small or medium size businesses, there are some low cost advertising techniques that can be used. A number of such methods are described bellow.

- **Giveaways.** People always like to receive free items and especially items that can be used to increase their knowledge or improve their way of living. One can build an entire advertising and promotion campaign based on this customer desire. For example a furniture business can give away free planning guides or free repair instruction manuals. Both items can be very attractive to customers or the public in general and giving them away can produce positive comments about the business. Also giving away such specific items can have the result of the business being perceived as an expert in the field of furniture planning or repairing.
- **News Creation.** Publicity about one's business in the newspapers (local or national) can be a very easy thing for someone to accomplish without the cost of having an advertisement inserted in the newspaper. The recruiting of a new associate, the selling of an unusual product, a free advice column concerning the sector that the business is in, the announcement of receiving an award or a grant, can be news that a newspaper will be interested in and that would attract the attention to many potential customers.
- **Events.** One can easily attract the attention of media or a crowd by staging a promotional event. For instance a business that manufactures children's food can arrange a lunch with a "Easter Bunny" during the Easter holidays.
- **Charities.** In the case of launching a new product and when the business is targeting a specific market segment it would be a great idea to offer the product to a charity as a raffle price at a fund raising event. Not only the product will be known but also the business.
- **Contests.** As with the case of charities one can use contests to promote his / hers product. The business must choose a contest that is relevant to the products that is manufacturing or selling. For example an eating contest will be a great promotion activity for a food manufacturing business.
- **Couponing.** This method can be applied after the launch of a new product. Giving away discount coupons can increase both the sales and the company publicity. Coupons can be handed out through magazines, newspapers, store counters, door-to-door mail, or hand by hand at locations where big crowds are gathering such as shopping malls, athletic events, social events etc.
- **Badges and Novelties.** One can easily and inexpensive produce badges, bumper stickers, book covers and other novelties that bear the company name or a smart slogan that is related to one's business. These can be distributed free by the same methods that are described above in the case of coupons.
- **Parties.** Everyone enjoy and attend parties. These can be held at the company's premises and celebrate the anniversary of the company or some special holiday. This is great way of getting publicity not only about one's company and its products but also its facilities and employees.

7.1.6.1C Product Placement

Product or brand placement is a form of advertising in which a product or a brand name is inserted intentionally in motion pictures and television programs. The product or the brand name can be mentioned in the dialogues, can appear in the set, can be used by a character or can be seen in vehicles or billboards. The product or the brand name can also appear in commercials inserted in the motion film. These commercials usually are made for use in the specific motion picture. This kind of advertising is also known as stealth advertising.

Brand placement usually begins with the studio representatives contacting brand marketers or their advertising agencies and informing them of the film's potential for product placement. If the marketers or the advertising agencies are interested then the film's scripts are sent to them for review and for placement strategy formation. If everything goes well some negotiations take place regarding cost, availability, merchandising opportunities and promotion of the product, brand name or film.

Brand or product placement offers marketers some great advantages over other kind of advertising methods. The greatest of all is cost efficient communication. Over the life cycle of a film, a film will be shown in theatres for a period of time, then maybe on television and then released on DVD or VHS. As time goes by the cost of advertising per viewer or viewing decreases. So product or brand placement maybe thought expensive at start but is very cheap in the long run. Also another great advantage is that the product advertising through placement lacks competition since it is run in an environment that is clean from other advertisements of competitive products.

Sometimes marketers require guarantees of audience attendance and always prefer lengthy theatrical viewings. This is due to the fact that in the dark environment of a theatre the advertising through product or brand placement has the maximum effect on viewers.

Brand or product placement is commonly directed to large corporations or companies since they are usually the ones with the money available to embark in such an advertising adventure. Nowadays the method is also used in the case of video games and music videos.

7.1.6.2 Personal Selling

Sales, or the activity of selling, forms an integral part of commercial activity. The primary function of sales is to find and close leads, turning prospective customers into actual ones. Forms of selling include:

Direct Sales - involving face-to-face contact
1. Retail or consumer
2. Door-to-door or travelling
3. Business-to-business

Indirect - human-mediated but with direct contact
1. Telephone or telesales
2. Mail-order

Electronic

1. Web B2B, B2C
2. EDI

Agency-based
1. Consignment
2. Multi-level.
3. Sales agents (real estate, manufacturing)

7.1.6.3 Publicity & Public relations

Public relations (PR) is the practice of conveying messages to the public through the media on behalf of a client, with the intention of changing the public's actions by influencing their opinions. PR practitioners usually target only certain segments of the public ("audiences"), since similar opinions tend to be shared by a group of people rather than an entire society. Communication is more regarded as an instrument and the "media" as one of the possible channels. The rather simplistic view in the first sentences doesn't explain internal relationship management and communication activities carried out by public relations practitioners. Nor does it explain community relations and activities.

Many people criticize the PR industry for its influence on the public, and for its sometimes unethical actions in pursuing a preferred message over the facts. However, to say that of all PR practitioners would be inaccurate. Most do not work for the large, multinational agencies, but are rather in-house employees of organizations, like companies, nonprofit organizations, and federal and local governments. Most are concerned with gaining any publicity for their clients or employers in the first place rather than "spinning" a controversial issue over a prolonged period. The "spinning" that the industry's critics complain of generally occurs in the service of large corporations and prominent issue advocates rather than the rank-and-file of the PR industry, though the amount of "spin" that can be bought with either financial or political capital does have a strong influence on public discourse

Publicity is closely related to public relations. Whereas public relations is the management of all communications between the firm and the general public, publicity is the management of product or brand related communications between the firm and the general public. It is primarily an informative activity (as opposed to a persuasive one), but its ultimate goal is to promote the companies products, services, or brands. A publicity plan is a planned program aimed at obtaining favourable press coverage for a companies products.

The most basic tool of the publicist is the press release, but other techniques include telephone press conferences, in-studio media tours, multi-component video news releases (VNR's), newswire stories, and internet releases. For these releases to be used by the media, they must be of interest to the public (or at least to the market segment that the media outlet is targeted to). The releases are often customized to match the media vehicle that they are being sent to. Getting noticed by the press is all about saying the right thing at the right time. A publicist is continuously asking what about you or your company will pique the reader's curiosity and make a good story? The most successful publicity releases are related to topics of current interest. These are referred to as news

pegs. An example is if three people die of water poisoning, an alert publicist would release stories about the technology embodied in a water purification product.

But the publicist cannot wait around for the news to present opportunities. They must also try to create their own news. Examples of this include:

- Contests
- Walkathons
- Art exhibitions
- Event sponsorship
- Arrange a speech or talk
- Make an analysis or prediction
- Conduct a poll or survey
- Issue a report
- Take a stand on a controversial subject
- Arrange for a testimonial
- Announce an appointment
- Celebrate an anniversary
- Invent then present an award
- Stage a debate
- Organize a tour of your business or projects
- Issue a commendation

The advantages of publicity are low cost, and credibility (particularly if the publicity is aired in between news stories like on evening TV news casts). The disadvantages are lack of control over how your releases will be used, and frustration over the low percentage of releases that are taken up by the media.

7.1.6.4 Sales Promotion

Sales promotions are non-personal promotional efforts that are designed to have an immediate impact on sales. Sales promotion is media and non-media marketing communications employed for a pre-determined, limited time to increase consumer demand, stimulate market demand or improve product availability. Examples include:

- Coupons
- Discounts and sales contests
- Point of purchase displays
- Rebates

Sales promotions can be directed at either the customer, sales staff, or distribution channel members (such as retailers). Sales promotions targeted at the consumer are called consumer sales promotions. Sales promotions targeted at retailers and wholesalers are called trade sales promotions. Some sale promotions, particularly ones with unusual methods, are considered gimmicks by many.

7.1.6.4A Consumer Promotion Techniques

The most known and used techniques of consumer sales promotional techniques are given bellow. These are mostly used in large retailer establishments such as super markets and shopping malls.

NAME	DESCRIPTION
Price deal	A temporary reduction in the price. For example “happy hour”.
Cents-off deal	Offers a brand at a lower price. Price reduction may be percentage marked on the package.
Price-pack deal	The packaging offers a certain percentage more of the product for the same price.
Coupons	Coupons that offer reduced price on a product or even a free product are common practice today.
Free standing insert	A coupon booklet that is offered inside newspapers or magazines containing price reductions on selected products.
Rebates	Consumers are offered money back if the receipt or the bar codes of a product are mailed back to the manufacturing or promotion company.
Contests / Games	The consumer is automatically inserted into a game or a contest with a high value price by purchasing a specific product.

7.1.6.4B Trade Promotion Techniques

The most known and used techniques of trade sales promotional techniques are given bellow.

NAME	DESCRIPTION
Trade allowances	A short-term incentive offered to make a retailer to stock up on a product.
Dealer loader	An incentive offered to make a retailer to purchase and display a product.
Trade contest	A contest to reward retailers that sell the most of a specific product.
Point of purchase displays	Extra sales tools given to retailers to boost sales.
Training programs	Dealer employees are trained in selling a specific product.

Push money	An extra commission paid to the retailer employees to push a specific product.

8. General Purpose Tools

8.1 Benchmarking Tool, Urenio Research Unit

Benchmarking is the process in which a company's practices, technology, production process, and its actual products are evaluated comparative with other companies of the same filed of activities.

In the case of this NPD roadmap a tool can be used to evaluate the entire above characteristics comparative to European best organizations in the same field. The performance of a company is evaluated through financial data, administration and management, strategy, R&D, manufacturing, engineering, products and marketing, quality and customer satisfaction and warehousing and distribution.

Benchmarking as a tool can be used either at the beginning or at the end of the NPD process. It can reveal strengths and weaknesses of the company when used at the beginning of the process and evaluate the result of the process when used at its end.

URENIO Research Unit offers benchmarking in this form online at http://www.urenio.org/benchmark/index.asp.

8.2 Business Process Reengineering

Business Process Reengineering or Redesign (BPR) is a method of finding the optimum processes or tasks that result in cost cutting, efficiency and productivity optimization and better work - business performing. Companies on the brink of disaster to cut costs and return to profitability often use it. Also it can be used to optimize resources in complex projects so that efficiency is optimized.

BPR must be accompanied by strategic planning, must be "owned" throughout the organization, must include the IT section of a business, must be sponsored by top executives, must have projects with strict timetables of the range of six months and must not ignore corporate culture and emphasize constant communication and feedback.

It can be applied to literally all sections or departments of a business: from human resources to research and development, from marketing to sales and from production to quality control.

8.2.1 Business Process Reengineering Methodology

There is a 5-step general methodology for BPR. This is described bellow.

- **Development of business vision and process objectives:** BPR is driven by a business vision, which implies specific business objectives such as cost reduction, time reduction and output quality improvement.

- **Identification of the processes to be redesigned:** Most businesses or firms try to identify these processes that have the most impact on the business vision. Other firms try to identify all the processes within the organization and then prioritize them in order of redesign urgency.
- **Understanding and measurement of the existing processes:** All processes must be fully understood and measured so that mistakes are not repeated during redesign and a baseline for redesign is provided.
- **Identification of IT Levers:** IT capabilities that influence or that may have an impact on the processes redesign must be identified.
- **Designing and building a prototype of the new process:** A process should not be altered immediately but a prototype of the new process should be designed and build so that the new process can be accessed before implementation. This allows the quick delivery of results without mishaps and bugs.

8.2.2 References

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8.3 Collaborative product development

A very few firms or businesses nowadays have the resources to undertake a complex new product development project. Usually they tend to concentrate on core technologies required for product development and rely on outside sources for complementary skills and resources. Also as markets become more and more competitive, downsizing has led a lot of companies in outsourcing to get the skills needed for product development. The following figure shows typical NPD operations and the way collaboration with outside sources can be achieved.

A typical co-operation NPD project must go through a number of stages to be successful. Usually the stages that are used are: Preparation, Formation, Management, Evolution and Conclusion. Each stage activities and the problems that may arise are given in the following table.

Table 1. Collaboration Stages, Activities and Problems

STAGE	ACTIVITY	PROBLEMS
Preparation	Product development strategy. Product design. Deciding what to do in-house.	Not enough information exists on in-house potentials. Partner may have a hidden

	Identifying partners. Performing partner selection.	agenda. Partner is not fully accessed.
Formation	Setting ground rules. Agreeing commercial terms. Setting copyright issues. Definition of communication channels.	Overestimating partner's capabilities. Very strict or rigid rules may slow down partners and the entire process. Being too cautious and mistrustful may have the effect of not achieving a win-win solution.
Management	Open and regular communications. Identification of risks. Adequate resources allocation.	Sometimes managers that run the project are not advised in forming it so renegotiations are required. Incompatible metric systems, time zones, file formats and software tools may be a problem. Incompatible business practices and cultural differences may also be a problem.
Evolution	Adapting to new facts and problems quickly.	Process required to be resourced due to partner inability to achieve goal.
Conclusion	Planning for long-term production and support. Learning from any mistakes that have been made.	Support agreements must be in place. Uncertainty over joint assets, materials or inventory.

Very few small and medium size companies have experience in dealing with collaborative projects. The table bellow illustrates the levels of collaborative maturity of companies and the problems that exist in each level for each NPD activity.

8.6 Product Outsourcing

Developing a new product concept to a reliable and feasible new product can require resources and time commitment that a company cannot spare. It may also require engineering tools and expertise that may not be available or too expensive to acquire. To overcome these problems and many more that could surface during new product development many companies turn to Product or Process Outsourcing.

Outsourcing is really the situation when a company or business gives a task to someone else that can do it more effectively. In the case of product development, outsourcing means the hiring or external contractors to develop a product concept into a product. It allows the company to take risks, reduce operating costs, free-up resources, improve its market focus, and be flexible to sudden market changes. Although outsourcing can be used in most of the major business functions of a

company, such as payroll, market research and logistics, its use can be vary successful in R&D processes due to the very complexity of such processes.

Outsourcing must be careful designed, the outsourcer - company relationship must be very well managed and the outsourcing results must be thoroughly benchmarked. Also the outsourcing process must be assessed beforehand so that one would not embark in a process that it is not useful.

Table 1: Outsourcing Assessment and Possible Results.

Outsourcing Assessment	Assessment Results
Identification of outsourcing costs	Pint point unexpected costs that are not explicitly in the scope of outsourcing such as personnel related costs, costs of additional resources and costs due to confidential information leaks that can lead in legal liabilities or competitive disadvantage.
Determination of Service Levels Agreements (SLA's)	Determine what is needed and expected though each stage of the outsourcing process and set levels of commitment of the outsourcer.
Flexibility check	Determine outsourcer flexibility and remove inflexible work practices.
Investigation of the form of penalties	Pre-set standards that an outsourcer must uphold and penalties that may imposed to the outsourcer in the case of no compliance of those standards.

Source: Australian Quennsland Government

Managing the outsourcing process is a task difficult by itself. The essence of outsourcing is to transfer the company's focus from managing resources and processes to managing results. So outsourcing management centers on the management of the outsourcer performance. Careful contracting, well-defined result benchmarking and quick resolution of disputes can do just this. Also the creation of a scoreboard of the behaviour of the outsourcer and of the end result may appear extremely helpful. Such a scoreboard is shown bellow.

Table 2: Possible Outsourcing Scoreboard

Criteria Evaluated	Sub Criteria	Possible Metrics
Experience	Specialized Knowledge	
	Technology know-how	
Communication	Presentations	Number / Month
	Frequent updates	Number / Month
Contract uphold	On-time delivery	% Above time set
	Budget keep	% Above budget set
	Contract terms uphold	No of penalties imposed
Efficiency	Completion on schedule	
	Quality end result	

	Goal achievement	

Source: Avlonitis G.

Most companies decide to outsource the development of a product concept or the development of a part of the product concept, feeling very confident that this action will save them money and time. The main mistake a company is bound to make is the impression that outsourcing is a good deal just because the outsourcer's product developing cost is lower than the company's. This can many times lead to poor quality products and subsequently dissatisfaction and grief. So benchmarking is required to provide a baseline of costs and service levels. Also benchmarking can be used for contract refinement and contract negotiations.

What to do and what don't for successful outsourcing

Five do's of successful outsourcing

- One must outsource the "bottlenecks", the things that are really keeping the company from growing profitably.
- One must pick great partners, check them out and speak to their customers.
- Once outsourcing is done, the outsourcer must be regarded as part of the company and treated as such.
- One must demand excellence, since outsourcing is what the outsourcer does for a living.
- Outsourcing might scare employees. One must communicate honestly with them.

Six mistakes in outsourcing

- Not really defining the desired results and they could be measured.
- Not talking to the outsourcer current and past clients.
- Failing to consider long-term relationship dynamics.
- Not planning up-front on how the company-outsourcer relationship will end.
- Treating the outsourcer as an outsider.

Four inhibitors to outsourcing

- Fear of loss of control.
- Work viewed as too strategic.
- Company's unique culture.
- Measuring the value.

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8.7 Portfolio Management

Portfolio management has to do with how a person or a company invests his product development resources, how project are prioritized and how resources are allocated across development projects. Portfolio management treats R&D investments much like a manager treats his investments in a stock market.

There are four goals in portfolio management: maximizing the value of the portfolio, looking for the right balance of projects, making sure that all the projects are aligned and making sure that one does not have too many projects for his given resources. There are a number of tools that can help someone to choose the right portfolio. These can be quantitative, graphical and strategic. Each of the portfolio goals is analyzed bellow.

Goal 1: Maximizing the value of ones portfolio. The goal in this case is to select a new product project so that to maximize the sum of commercial worth of all active projects in terms of some strategic objective. Tools that can be used in this case are:

- Net Present Value (NPV). One could calculate the net present value of each project and then rank all by the outcome of NPV divided to a constrained predetermined value. For example a predetermined value could be remaining - unspent R&D costs. Projects can be ranked according to this index until out of resources. This way the value of the portfolio is maximized for a given limited resource expenditure.
- Expected Commercial Value (ECV). This method uses decision tree analysis i.e. breaking the project into decision stages for example R&D, prototyping, testing, commercialization. All possible outcomes of the project combined with the probability of each of them occurring are defined. The resulting ECV is divided by a pre determined constrained resource as in the case of NPV and projects are ranked according to the resulting index.

- Scoring Model. During this method decision makers rate projects according to a number of questions. Depending on the answers given projects are ranked in a 1 to 5 or 0 to 10 scale. Addition of these rating makes up the quantified Project Attractiveness Score, which incorporates strategic, financial and other considerations. The projects are ranked according to the PAS until resources run out.

Goal 2: Balancing ones portfolio. In this case the goal is to balance all projects according to a set of parameters. These parameters can be time, risk factors, product types, different markets, project types etc. The techniques used to achieve this goal are mainly graphical. The most used ones include bubble diagrams and pie charts.

Goal 3: Portfolio Alignment. Portfolio alignment means that all the projects should be on target in terms of the strategy and all spending should reflect ones strategic priorities. Several tools have been designed to align ones portfolio. Such tools are the "Top-down Strategic Buckets", "Top-down Product Roadmaps" and the "Bottom-up".

Goal 4: Picking the Right Number of Projects. Many companies have too many projects running at the same time and limited resources. The result is that projects end up in a queue and products make too much time to reach a market. So an over-riding goal is required so that a balance is maintained between projects and resources available. This can be done in several ways, some of which are given bellow.

* Resource limits. Using the tools that are mentioned in the case of the 1st goal one can build a resource limitation and projects can be ranked until the company is out of resources. The same occurs if the Bubble Diagrams are used.

- Resource Capacity Analysis. In this case one should calculate the resource demand, prioritize projects from best to worst, and add up the resources required by the R&D department for all projects. Using then some kind of software toll such as MS Project the available resources per project per month can be determined. The outcome of this exercise is the identification of the projects or departmental groups that are hold back due to the lack of resources.

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