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System Design for Sustainability

Learning Unit 1 The design process

Author

Dr Davide Paciotti-Unicam University-IT

Licences

Funding

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- Will give you the ability to relate the form to the use for which it was conceived, to the technical modalities that have enabled its concrete realization.
- And to be able to verification of the performances required of the product.

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The Design Process (Formal synthesis of product)

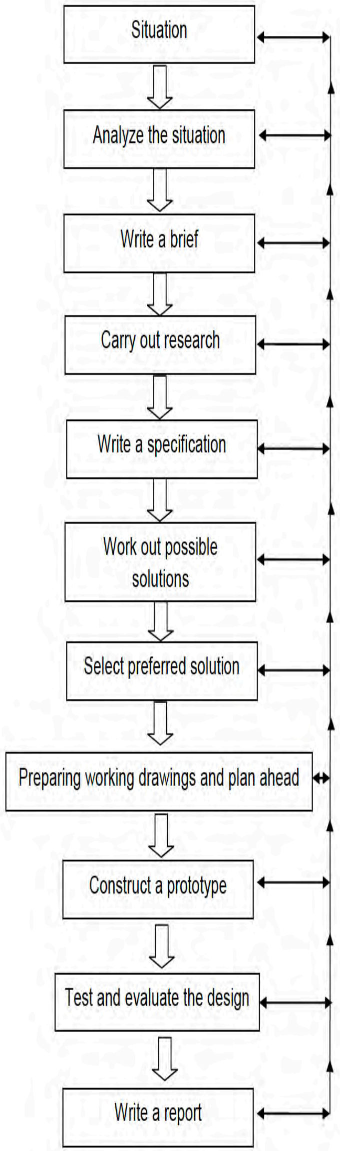
The Longman dictionary [1995] defines a product as “something useful that is made in factory, grown, or taken from nature”. Ulrich and Eppinger [1995] describe a product as “something sold by an enterprise to its customers”. Baker and Hart [2007. P41] have defined a product as “the object of the exchange process, the thing which the producer or supplier offers to a potential customer in exchange for something else (e.g. money) which the supplier perceives as being of equivalent or greater value”.

Product design process

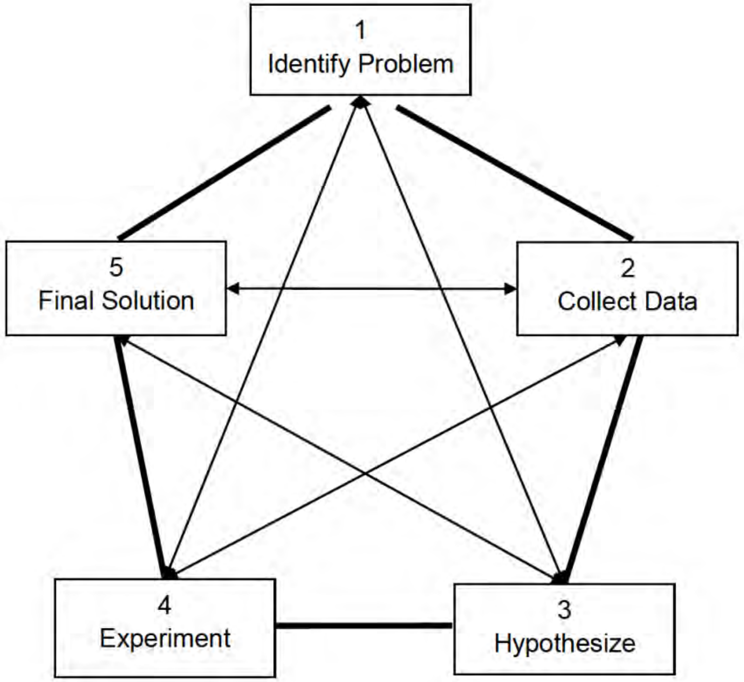
In practice, the process of design is extremely complex and is subject to many different influences and factors. Not least of these are the constraints imposed by the social, economic, political, cultural, organizational, and commercial contexts within which new products are developed, and the character, thinking and creative abilities of the individual designers or teams of designers, aligned specialists and manufacturers involved in their realization [Charlotte and Fiell 2003].

At the simplest level, the product design process may be classified into three traditional stages: specification development, conceptual design and embodiment design [Ehrlenspiel 2003]. However, similar to the NPD models, there are various product design models in practice. Within these types of design models from researchers, the vast majority of them still have similar core stages [Hollins and Hollins 1991]. In the following sub-sections, several Design Models devised by scholars are reviewed and analysed.

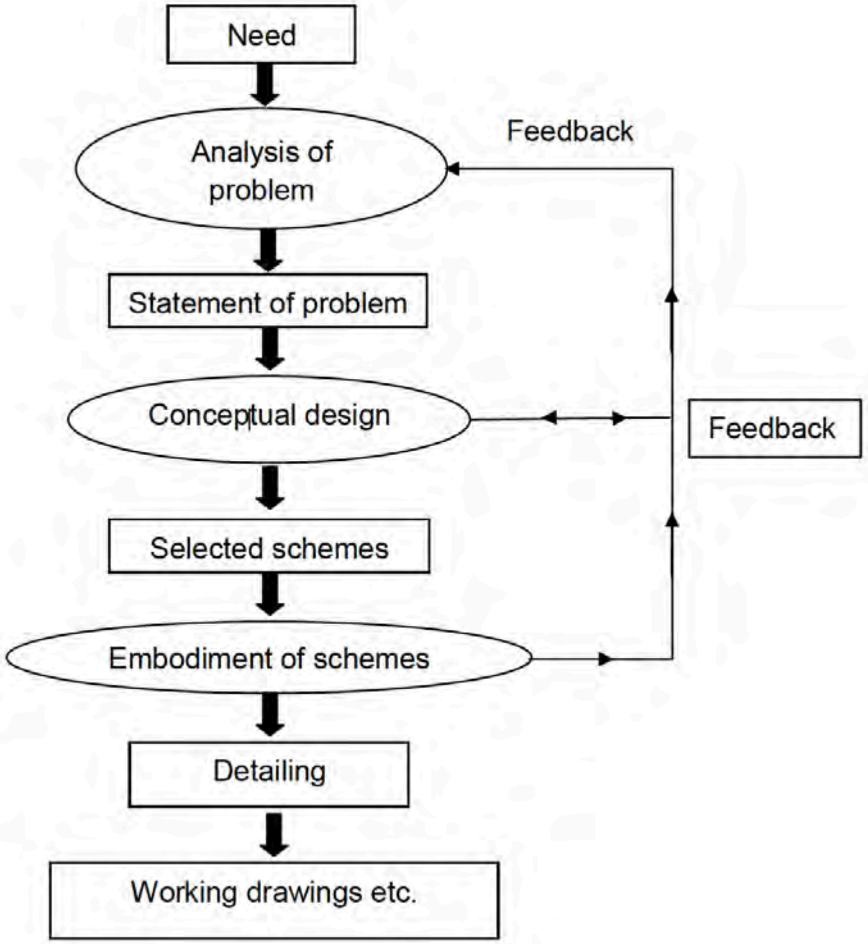
Model one [Garratt 1991]



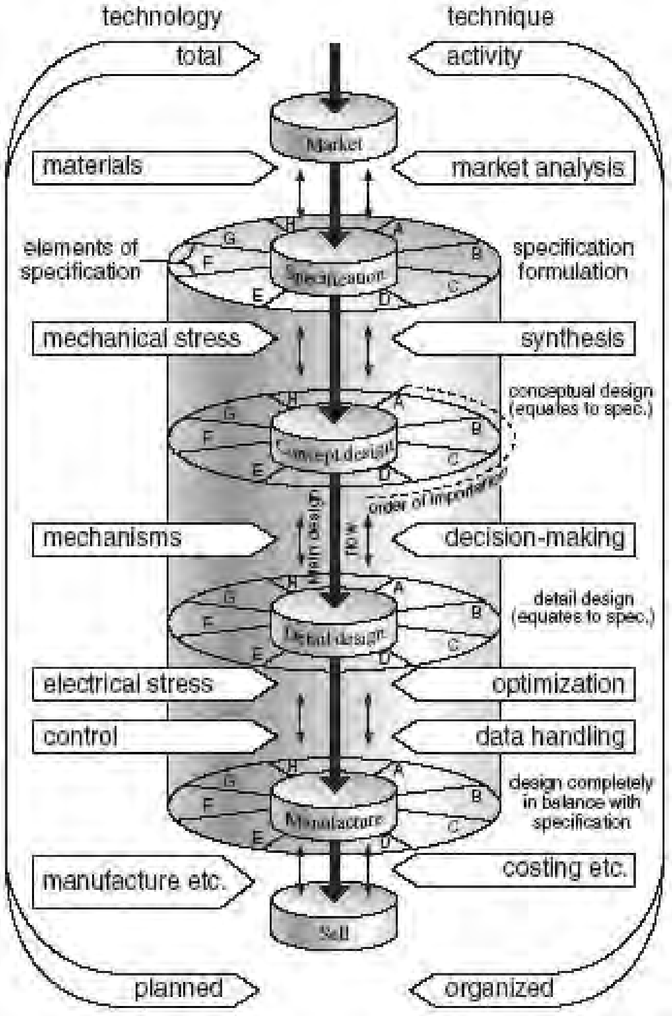
Model two [Lindbeck 1995]



Model three [French 1999]



Model Four [Pugh 1990]



The characteristics of product design

Compared with other disciplines and professions, such as science, engineering, fine art, etc., product design has some typical characteristics. Based on a review of previous research, some of these characteristics include, but are not limited to, the following:

1. Product design is an activity that adds value to products
2. Product design is a creative and innovative and activity
3. Product design is a cross disciplinary activity
4. Product design is neither a precise science nor a fine art
5. Product design is an art of trade-off
6. Product design is an iterative process

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System Design for Sustainability

Learning Unit 2 Virtual and physical prototyping

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Dr Davide Paciotti-Unicam University-IT

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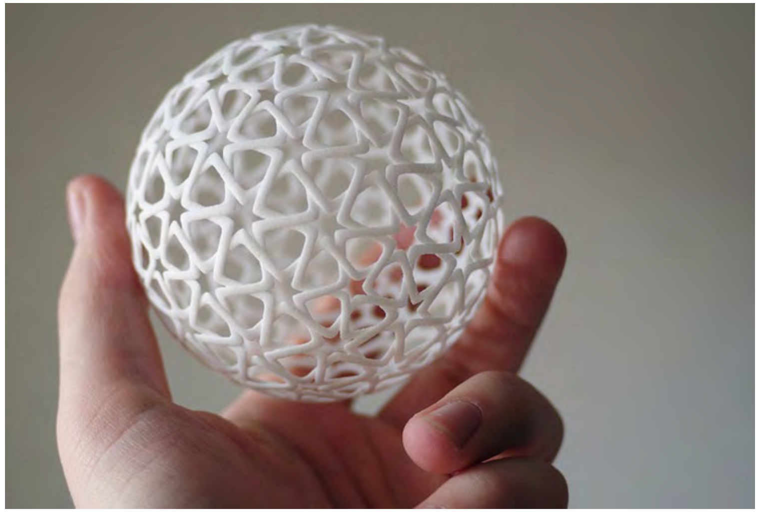
Virtual and Physical Prototyping

Prototype is a wide ranging concept and has specific meanings in different domains, such as computing science, metrology and pathology, etc. In product development, there are two other similar concepts to prototype: model and mock-up.

In Longman dictionary [1997], model refers to a small copy of a building, vehicle, machine etc. ‟, *while mock-up is described as a full-size model of something that is going to be made or built.*

The role of prototype/prototyping in product design process

Prototyping is the pivotal activity that structures innovation, collaboration, and creativity in design [Hartmann et al 2006]. Schrage [1996] stated that companies that want to build better products must learn how to build better prototypes. In the product development process, prototypes play a key role at almost every stage, from early concept development until preproduction [Stoll 1999, p131], and every aspect of the product must be considered and approved by the designer and client with prototyping [Slack 2006].



Classifications

During the design and development of a new product, different classes of prototypes will be built sequentially to meet different testing tasks. As Schrage [1996] stated, not all prototypes are the same, either in how they are built, or in the role they play in the design process.

Classes	description
Early "proof-of-concept" models	which help the development team to demonstrate feasibility
"Form-only" models	which can be shown to customers to evaluate ergonomics and style
Spreadsheet models and experimental test models	which can be used to set design parameters for robust performance

Classes	description
Concept prototype	which is useful for exploring preliminary design ideas quickly and inexpensively
Throwaway prototype	which is useful for collecting information about the functionality and performance of certain aspects of a system
Evolutionary prototype	which is useful when many design specifications are uncertain or changing

Classes	description
Crude model	enables you to get a better feel for the basic premise of your invention
Working prototype	allows users to try out some or all of the features of the invention
Final prototype	a model that looks and functions almost like a manufactured product

Besides the above methods of classification, all prototypes can also be generally categorized into physical prototypes as opposed to virtual prototypes [Stoll 1999, p131].

A physical prototype refers to a model made from real materials and substances, while a virtual prototype basically means a model created in computer.

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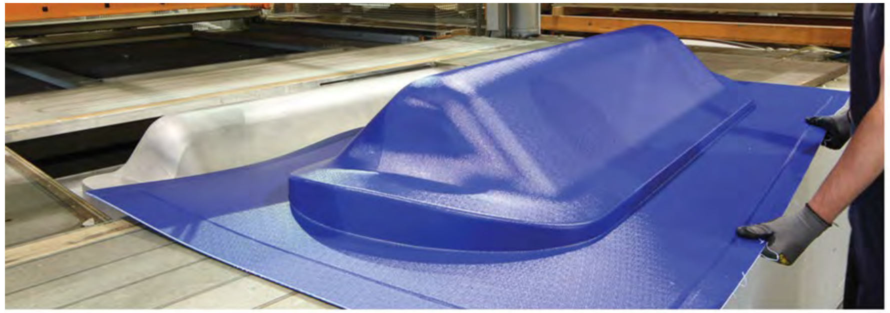
Prototypes can also act as a medium for managing risks [Schrage 1996], and are extremely important tools for improving the quality of design decisions [Stoll 1999]. In the early conceptual development stage of a product design, prototyping is usually used to test the feasibility of design, uncover unpredicted phenomena, catch design flaws and change directions [Otto and Wood 2001, Medero 2007].

Prototypes can act as communication and demonstration tool to show them the accomplishment of project goals and milestones and obtain feedback from suppliers, vendors, and management [Otto and Wood 2001].

Physical Prototypes: Definitions and classifications

A physical prototype, as the name suggests, is an object in the real world. It is a tangible artefact [Ulrich and Eppinger 2003], and made with miscellaneous materials such as wood, clay, foam, metal, plastic or even paper [Zorriassatine 2003, Medero 2007]. Wallentin [1999] defined physical prototypes as hardware models created to approximate the product and for testing and experimentation. Otto and Wood [2001, p 838] stated that "a physical prototype is an object (or set of objects) that is fabricated from a variety of materials to approximate an aspect(s) of how a product concept performs".



A typical type of plastic used in prototyping is Acrylonitrile Butadiene Styrene (ABS). ABS plastic has a good balance of properties.

Methods of physical prototyping

Physical prototyping technologies range from simple models made with common hardware and simple materials to precision prototypes made with specialized processes and advanced materials [Otto and Wood 2001]. These technologies are extensive, from traditional hand crafting to advanced computer-controlled prototyping. According to the tools involved, the methods of physical prototyping can be classified into three types.

1. Hand making is the most traditional and is probably the most flexible way to create prototypes. People could use any hand tool, even just their hands, to create a prototype. These tools might be hammer, carving or sculpting knives, screwdriver, scrapers, etc.
2. Mechanical machining the designers usually need to create some wood models with the help of mechanical machines as vacuum forming machine.
3. Computer aided prototyping Two typical computer aided prototyping technologies are computer numeric control (CNC) and rapid prototyping (RP). These technologies can be used to create physical prototypes with high surface quality and/or a complex shape.

In practice, designers normally do not use only one modelling method to achieve the final prototype, but apply various methods in different phrases.

Virtual Prototypes: Definitions and classifications

A virtual prototype, or digital mock-up, is a computer simulation of a physical product that can be presented, analysed, and tested from concerned product life-cycle aspects such as design/engineering, manufacturing, service, and recycling as if on a real physical model. The construction and testing of a virtual prototype is called virtual prototyping (VP).

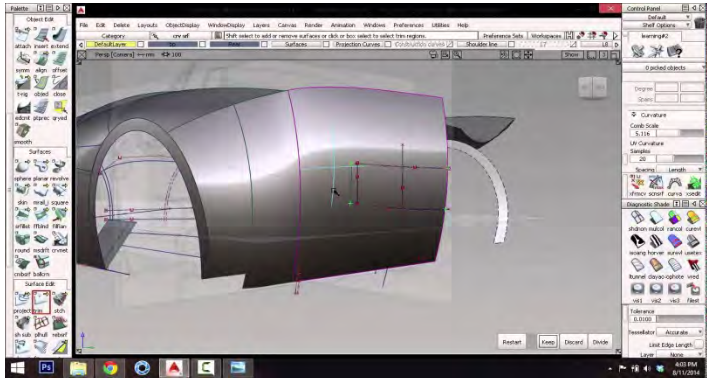
In order to reduce costs and development time, companies are increasingly turning to virtual prototyping methods during the early phases of design development. Such methods can range from sketches and renderings to detailed 3D computer models of potential designs. Visual representations are supplemented by physical models made using rapid prototyping equipment or traditional model-making skills [Design Council 2007].

In terms of the classification of virtual prototypes, Tseng et al [1998] classified them into two types, i.e. immersive virtual prototypes and analytical virtual prototypes. However, literally from those definitions, a virtual prototype is a general concept. In a different context, it might have many synonyms (Digital prototype, Digital Mock up, CAD Model, etc…).

Methods of virtual prototyping

The construction of virtual prototypes is usually achieved through 3D modelling software.

In addition, there are other technologies used in industry for testing and analysing virtual prototypes, such as computational fluid dynamics (CFD) and finite element analysis (FEA).



Besides the ability to build a 3D virtual model, most 3D modelling software has functions for testing and analysing virtual prototypes.

Criteria to indicate whether virtual or physical prototyping is more desirable

There are some situations where physical prototyping is more beneficial, while in many other situations, virtual prototyping is to be preferred.

A physical prototype usually allows human beings sensory evaluation of a product, such as form, tactile feel, softness, and so on. Product ergonomics are also an increasing concern.

	Virtual prototyping	Physical prototyping
cost	√	
time	√	
Ability of iteration	√	
Evaluation of ergonomics		√
Aesthetics	√	
tactility		√
Dynamic analysis	√	
Complex product	√	
Product with simple structure		√
Function test		√
User communication		√

Physical and virtual prototyping are valuable techniques that can join together to form a powerful tool for rapid development of complex products [Campbell et al 2004]. In the future, industry leaders will have both technologies providing the ability to select the best for the task at hand [Grimm 2005] or to combine their strengths together.

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Learning Unit 3 Integrated product policy and eco-product development

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integrated product policy and eco-product development

The purpose of this subject is to examine developments in the IPP initiative and how it may influence the development of 'greener' products (i.e. eco-product development [EPD]). The chapter will begin by examining the background, definition, objectives, principles, strategies, components and potential toolbox of IPP.

The purpose of this is to examine how some aspects of IPP may be expected to operate in reality. From this, a simplified perspective for IPP is proposed. Finally, the chapter looks at the relationship between IPP and eco-product development in companies, using the electronics sector as an example.

Integrated product policy (IPP)

Integrated product policy (IPP) is an initiative at the European Union (EU) level aimed at reducing the environmental burden of products and services throughout their life cycles by using a toolbox of policy instruments to 'green' markets through 'greening' both the demand side (consumption) and the supply side (product development).

IPP aims to :

- tackle the stage at which many of the environmental burdens of products are determined, thus reducing non-point source problems further in the lifecycle
- green the consumption side of the market by focusing on the way that customers (individual, business-to-business, distributors and governmental) choose, use and discard products and services

Background

It was not until the 1990s that EU member states began to formulate product-oriented environmental policies. The most prominent among these countries are the Netherlands, Denmark and Sweden, which are considered to be the leading countries, followed closely by Germany and Austria.

Environmental product policy (EPP) are also starting to emerge in Belgium, the United Kingdom and Finland. Countries such as France, Italy, Spain, Portugal, Greece and Ireland seem to be lagging behind.

Although there are significant similarities among the national policies developed so far, different elements and measures have been developed and different product groups targeted, which has resulted in a fragmented picture across Europe. One of the reasons for introducing a common EU approach to environmental product policy (i.e. IPP) is the necessity of harmonising these national approaches.

IPP and SMEs

SMEs face a number of barriers to addressing environmental issues and legislation that may account for this, for example:

- to access information on legislation and new Directives;
- poor environmental awareness, possibly due to a lack of easily understandable information;
- environmental aspects as constraints and costs instead of opportunities;
- time and resources allowing to respond only to immediate business threats that impact on the bottom line;
- Innovation motivated by environmental reasons.

Life Cycle Assessment (LCA) and other techniques are effective methods to assess the environmental impacts of your products and services and to determine how to reduce them.

The EcoSMEs.net tools are designed to remove the above barriers that may be preventing you from implementing and benefiting from IPP techniques.

Advantages of IPP for Business

Environmental Benefits

1. Reduced use of natural resources in manufacturing including raw materials, components, water and energy (Example: Fulleon Limited)
2. Reduced resource use in the use phase including water and energy use from improved process control (Example: Welbeck Fabric Dyers)
3. Reduced waste production at end of life and throughout the lifecycle (Example: Stadium Group plc Electronic Controls Division)
4. Reduced hazardous material content through substance bans (Example: Connaught Electronics Ltd)
5. Continuous improvement of environmental performance of products and services as the green market grows and new legislation is implemented (Example: Varian Medical Systems UK Limited)

Advantages of IPP for Business

1.Financial Savings

2.Increased Sales and Consolidated Market Share

3. Adding Value to Products

4. Marketing Tools

5. Compliance with Regulations

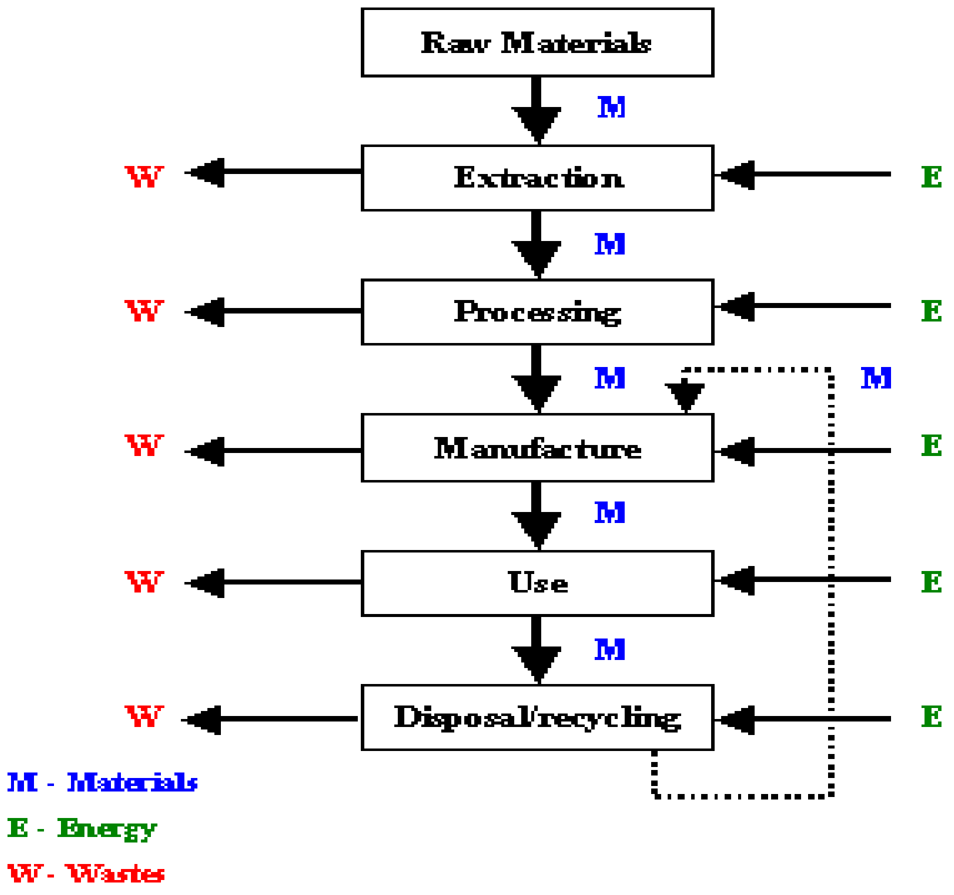
6. Improved Staff Skills and Knowledge

No.	Driver	Effects and Benefits for Your Company
1	GREEN PROCUREMENT	Green purchasing policies led by Government and large companies will develop the market for green products. If your company can demonstrate the environmental advantages of its products it will exploit this new and expanding market and increase market share.
2	‘GREEN PRODUCTS’ MARKET	Although not a new market opportunity IPP will greatly increase the size of the green products market over and above the niche market that it currently represents. Adopting IPP techniques such as life cycle thinking at an early stage can establish your company as a market leader and allow you to increase market share.
3	SUPPLY CHAIN PRESSURE	Large companies in the supply chain are already working towards compliance with new legislation and environmental reporting requirements. To ensure compliance they will demand that products and components from their suppliers also meet these criteria. If your company responds positively it will maintain and strengthen its position in the supply chain and improve relations.
4	PARENT COMPANY PRESSURE	If your company is governed by a parent company you are probably already experiencing demands to adopt IPP. Parent companies must ensure the compliance of all business units with the requirements of IPP and new legislation. You must prepare for these demands to maintain good relations.
5	TAKE BACK (PRODUCER RESPONSIBILITY) LEGISLATION	New legislation including the WEEE Directive places responsibility for collection and recycling of end of life products on the producer. If you manufacture products you must ensure compliance by adopting life cycle techniques. If you manufacture components or sub-assemblies you must comply to meet the requirements of your customers. Responding positively will help you maintain and increase market share.
6	PRODUCT ORIENTATED LEGISLATION	New legislation including the RoHS Directive will require materials substitution to reduce the environmental impacts of your products. Your company must apply eco-design techniques to products and components to ensure legislative compliance. You may even reduce materials costs and increase competitiveness and market share.
7	ENERGY REDUCTION INITIATIVES AND LEGISLATION	Proposed legislation including the EuP Directive will set requirements regarding environmentally relevant product characteristics (such as energy consumption) to enhance product quality and environmental protection. If your company manufactures products that fulfil the requirements it will, in addition to ensuring legislative compliance, reduce operating costs and increase its share of the green products market.
8	ENVIRONMENTAL REPORTING	Your company must meet increasing reporting requirements. The requirement for materials declarations from large companies is already common. Measuring and reporting encourages better management of resources leading to lower energy and water bills and reduced raw material use. Your company will also enjoy less tangible benefits such as better customer relations and the ability to show investors that it is acting to reduce environmental risk.
9	PRODUCT ENVIRONMENTAL IMPROVEMENT 'ADDED VALUE PRODUCTS'	Designing more environmentally sound products by applying eco-design techniques reduces impacts at all stages of the life cycle, including material inputs, energy and water use and waste generation, therefore reducing your costs. Your company will also benefit from an increased share of the green products market and improved customer and stakeholder relations.
10	ECO-LABELS; EPDs; ENVIRONMENTAL AWARDS	By adopting these tools your company can demonstrate the environmental advantages of its products and improve its position and share in the green products market. If you have achieved an eco-label, EPD or award it is likely that during this process you have gained many other benefits including; legislative compliance, reduced operating costs and improved environmental reporting.

Principles and Building Blocks of IPP

Such an approach should ensure that environmental impacts throughout the life cycle are addressed in an integrated way to avoid shifting impacts from one life cycle stage to another. This should also allow impacts to be addressed at the point in the life cycle where they will most cost-effectively reduce the overall environmental impact and resource use.

IPP seeks to achieve this environmental improvement whilst also supporting long term industrial competitiveness.



Key Principles of IPP

Integrated Product Policy (IPP) is based on a number of key principles:

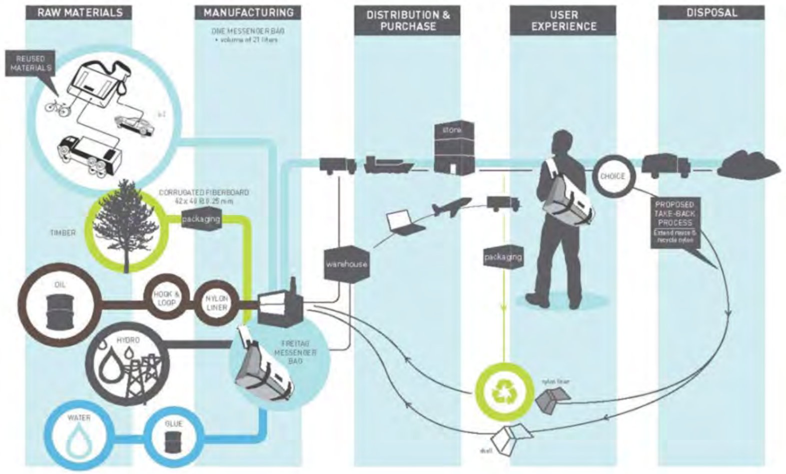
- Life cycle thinking
- Working with the market
- Stakeholder involvement
- Continuous improvement
- Flexible policy instruments

Considering the key principles of Integrated Product Policy (IPP), five policy building blocks have been developed that form the basis of IPP:

1. Reducing and managing wastes
2. Innovation of green products
3. Creating markets for green products
4. Transmitting environmental information up and down the product chain
5. Allocating responsibility for environmental burdens

Life Cycle Assessment

Life Cycle Assessment (LCA), considers the whole life cycle of a product. According to the Society of Environmental Toxicology and Chemistry (SETAC), LCA provides a way of assessing the environmental burdens associated with the whole life cycle of a product or service, from its cradle to its grave.



Cradle-to-grave

The LCA methodology evaluates all stages of a product’s life from the perspective that they are interdependent, meaning that one operation leads to the next. A life cycle for a product may therefore include:

- raw material extraction;
- transformation of these substances into common materials, such as plastic or semi-finished products;
- manufacture of the product itself;
- use and reuse of the product;
- recycling and disposal at the end of its useful life.

LCA provides a comprehensive overview of the environmental characteristics of that product or process and a more accurate picture of the true environmental trade-offs in product selection.

Why an LCA?

LCA can be used to aid decision-making during product, or process, design or re-design. Businesses can use LCA to compare the environmental impacts of different design options

LCA quantifies the inputs to, and outputs from, each life cycle stage of production. It will then relate these inputs and outputs to environmental impacts and specific environmental areas of concern.

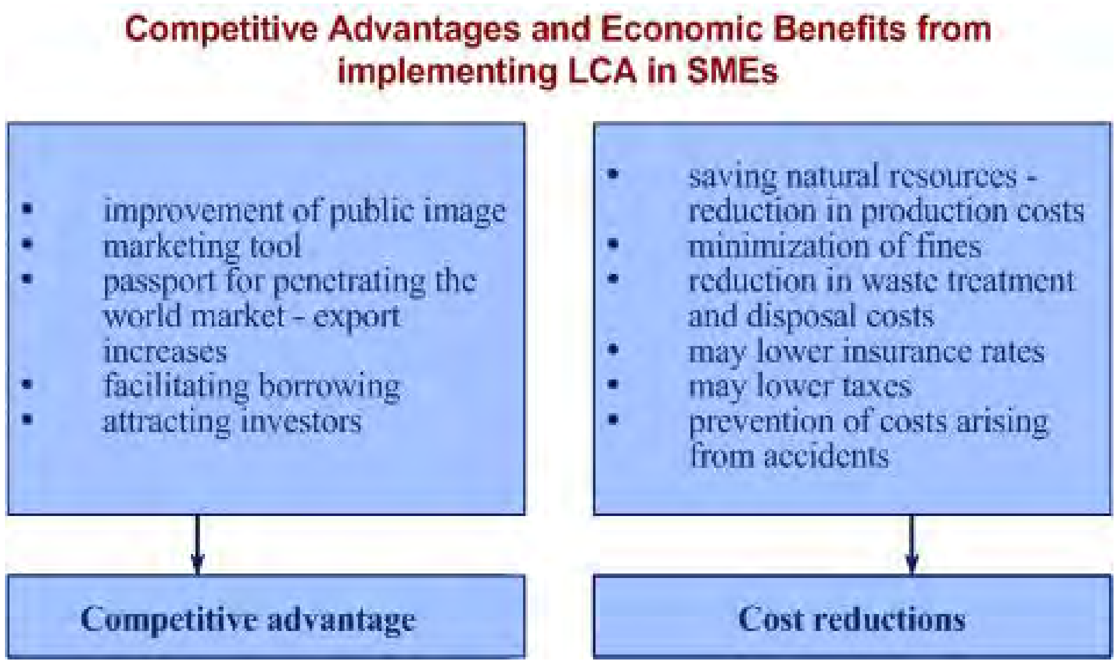
LCA can be used as a marketing tool. Consumers may prefer environmentally friendly products.

LCA examines a product's life cycle increasing the efficiency of resource use will lead to a reduction in the quantity of inputs used and waste produced, thereby reducing costs.

Why an LCA?

The LCA framework can be incorporated into environmental management systems (EMS) and environmental labelling schemes. There are both competitive and economic advantages of this.

- **Environmental management systems (EMS)**
- **Environmental labelling**



LCA and SMEs

LCA is a comparative tool and can help to increase an SME's competitiveness by

- **Calculate energy consumption and the environmental releases** of different product or process options. This will help you choose the most environmentally friendly and cheapest option.

- **Evaluate the environmental impacts associated** with each option and relating these to societal values. Thus a more environmentally friendly product can be promoted by using arguments that relate to social problems as well as environmental impacts.

LCA Applications

The main applications of LCA :

- investigate the source of problems related to a product or service
- compare options for improving a product or service
- design new products or services, e.g. make informed choices
- choose between a number of comparable products or services
- prepare environmental documentation e.g.

LCA is a technique that can help an SME to assess all of the inputs to, and outputs from, their production process following a step by step process:

1. **Compile** an inventory of energy and material inputs and environmental releases (e.g. emissions to air, solid waste disposal, wastewater discharge);
2. **Evaluate** the potential environmental impacts associated with identified inputs and releases;
3. **Interpret** the results in order to make a more informed decision.

Undertaking an LCA study

Formation of an LCA team

Milestone definition

Selection of personnel to carry out data collection

Briefing meetings

Progress monitoring

Review of LCA results and conclusions

The LCA team evaluates, checks and verifies the results of the LCA, as they will be used as the basis for the final conclusions of the study. Final conclusions will also have to take into account the company's economic or general policy concerns.

ISO 14040 framework

ISO standards include the 9000 and 14000 series. The 14000 series includes the ISO 14 001 standard on Environmental Management Systems (EMS), as well as a series of standards relating to LCA (the 14040 series). These ISO activities began in 1994 and aim to eventually produce the first complete series of LCA standards.

The ISO LCA standards concern both the technical and organisational aspects of an LCA. The organisational aspects mainly focus on the design of critical review processes, paying special attention to public statements. They also cover matters such as the involvement of stakeholders.

International Standards Organization (ISO) LCA Series

- ISO 14040: Principles and Framework
- ISO 14041: Goal, Scope & Inventory Analysis
- ISO 14042: Impact Assessment
- ISO 14043: Life Cycle Interpretation
- ISO 14047: Examples of Impact Assessment
- ISO 14048: Documentation Format
- ISO 14049: Examples of Inventory Analysis

ECODESIGN

Ecodesign is the incorporation of environmental considerations into the design and development of products or services. Ecodesign adopts an integrated approach to the relationship between products and services and the environment on three levels:

- *the whole Life Cycle of the product or service is considered;*
- *the product is considered as a system;*
- *a multicriteria approach is considered.*

In addition, European regulations recognise and emphasise producers' responsibility in minimising the environmental impacts of their products and services. Ecodesign can help producers to manage that responsibility and comply with product-related legislation.

Benefits of ecodesign for Small & Medium-sized Enterprises

- Reduced manufacturing and distribution costs by identifying any inefficient processes that can be improved and finding new ways to produce more with less.
- Stimulation of innovative-thinking inside your company leading to increased innovation and facilitating the creation of new market opportunities.
- Reinforced brand and product image because of your environmental consciousness and innovative attitude; see example of Demano bags.
- Compliance with environmental regulations. The requirements of existing regulations should be considered as the starting point for improvements.
- Improved quality of your products by increasing durability and functionality and by making them easy to repair and recycle. Different ecodesign strategies can be considered to achieve this.
- Increased added value of products that have better environmental performance through their entire life cycle and are also of better quality; see the example of office furniture produced by OFITA.
- Access to green purchasing markets
- Access to eco-labelling
- Increased knowledge of the product and processes involved in its life cycle for you can use for strategic planning, communication strategies or benchmarking your enterprise.

Key factors to successfully apply ecodesign in SMEs

The main points to be aware of in order to properly implement ecodesign in an SME are:

- set realistic objectives to be achieved gradually in the short, medium or long term
- ensure good integration of the environmental considerations and design culture among persons involved in the ecodesign process
- adopt life cycle thinking in order to improve the global environmental performance of products and services, learning about the consequences of changes in design and avoiding the potential transfer of environmental impacts
- obtain reliable and up to date information about the life cycle of the products or services to be ecodesigned. For this you require co-operation from other actors in the supply chain, i.e. suppliers of raw materials, distributors, customers, product end users etc
- use the most appropriate ecodesign strategies and environmental assessment tools according to the characteristics of your company and the objectives that you want to achieve
- find alternatives with lower environmental impacts in the materials you use and your manufacturing or distribution processes, and identify suitable providers for new product developments

Integration with other IPP tools

As a result of the integrated structure of ecodesign it can easily be used in conjunction with other IPP tools.

Type I Eco-labels

Type II Eco-labels

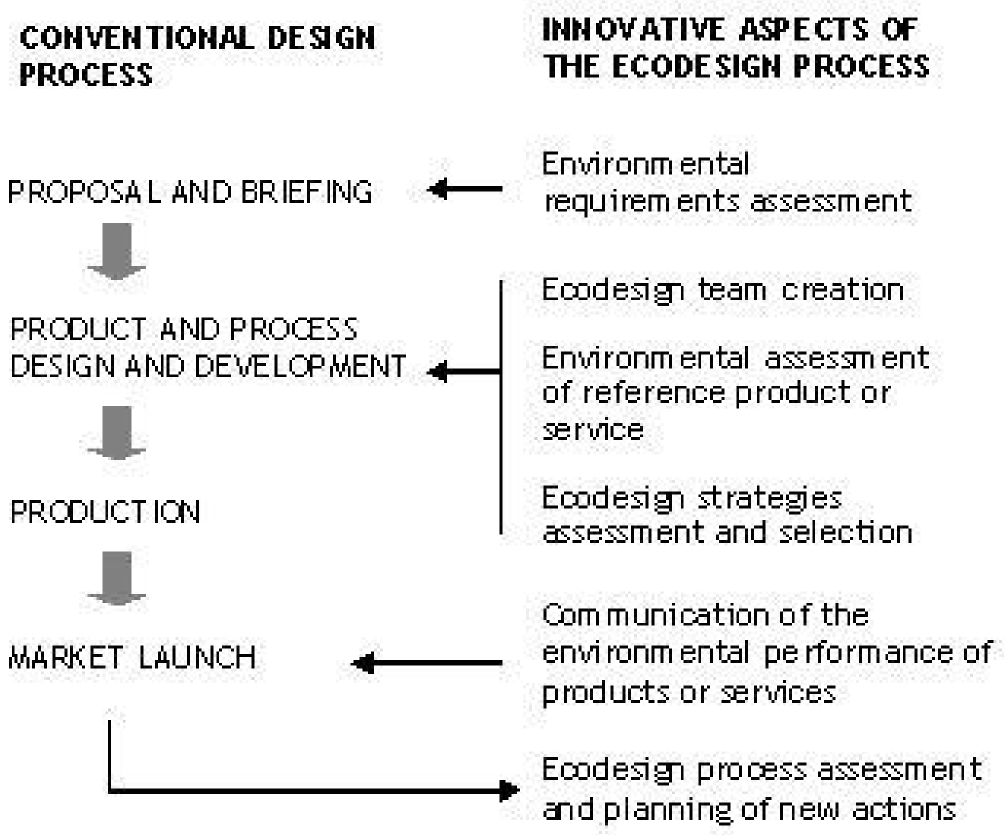
Green procurement

Environmental Management Systems (EMS)

Environmental Management Systems (EMS)

Life Cycle Assessment

Implementation of ecodesign in business



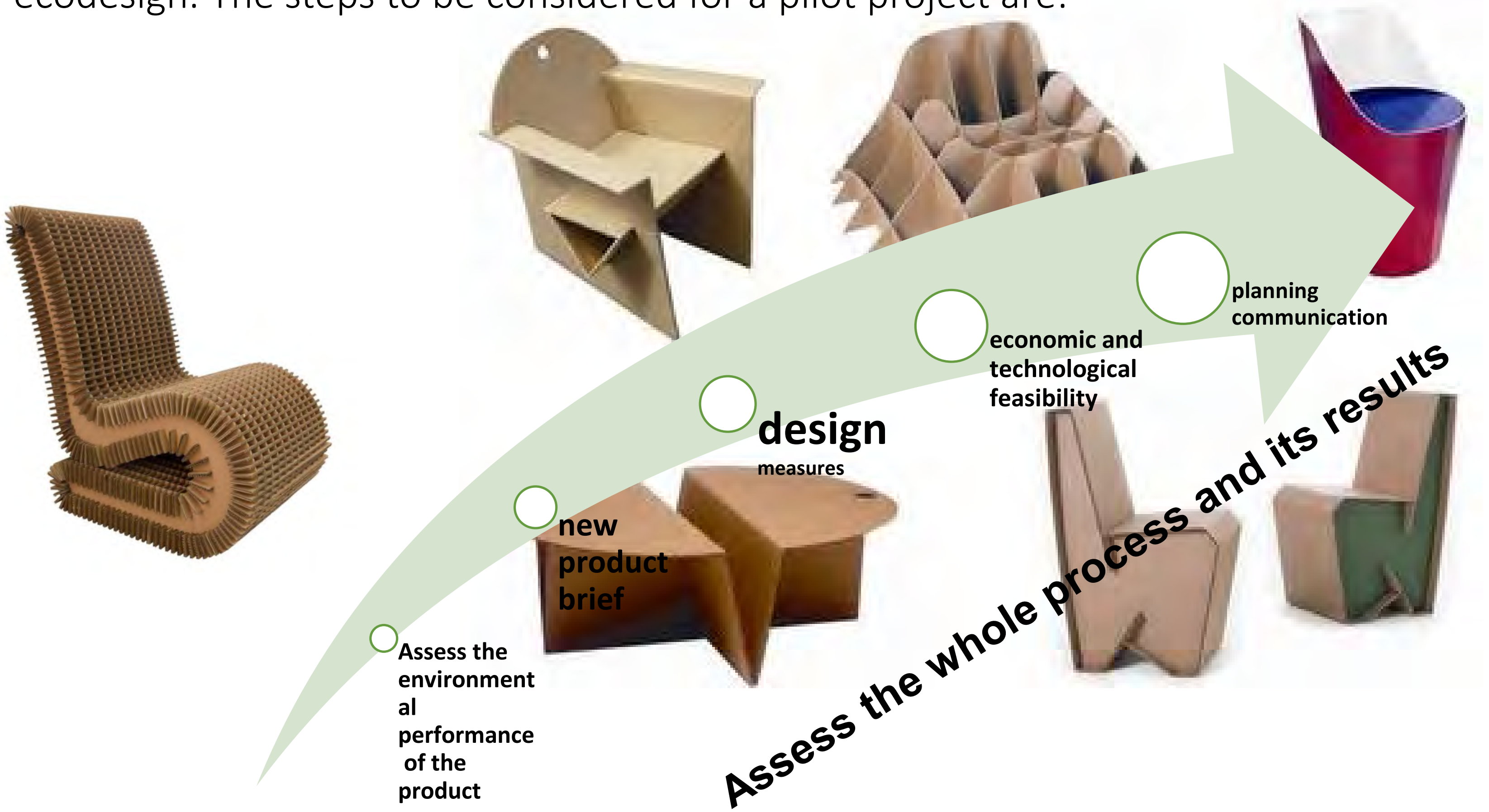
The conventional design process can be adapted into ecodesign by integrating some simple changes (see diagram below). The scope of these changes depends on your company's objectives. For example, the redesign of an existing product incorporating environmental considerations will not generate as much innovation as the creation of a new line of sustainable products.

Who has to take part in the implementation of ecodesign?

ACTOR	MAIN FUNCTION
Designer / design team	Generate ideas and translate them in practical measures that can be developed
Product engineer / production department	Assess the technological feasibility of proposed ecodesign changes
Environmental expert	Environmental analysis of the existing product, the alternative measures and the final ecodesigned product Participate in the definition of the scope and goals of the process
Marketing expert/ team	Participate in the definition of the scope and goals of the process and prepare the market launch of the ecodesigned product
Other responsible departments	Help to identify other aspects to be improved, in addition to the environmental ones Give opinions and ideas about the proposed measures and assess their economic feasibility
Process manager	Define the scope and goals of the process Participate in the final selection of measures to be applied in the new product Co-ordinate and ensure the participation of the other actors

Who has to take part in the implementation of ecodesign?

Some enterprises may find that they can adapt their product development to include ecodesign. The steps to be considered for a pilot project are:



Ecodesign strategy groups