A CONCEPTUAL EXAMINATION OF PRODUCT DESIGN, APPROPRIATE TECHNOLOGY AND ENVIRONMENTAL IMPACT

By Tony Murray. Revised June 2005

This paper explores the role of product design in industrialisation in both industrialised and developing countries. The skills required for successful design and the design process are described. The concept of appropriate technology and the role of product design in producing appropriate technologies is examined. The final section is about the issue of industrialisation and the environment and the role of product design in the supply of products which do not have a negative environmental impact, in their production, use or disposal.

The paper is an extract from a wider study originally written as a thesis for a masters degree in development studies. The rest of the study (not published here), provides an overview of the role of industrialisation in development, industrialisation theories; strategies and choices, and environment issues. The thesis presented the results of field research into one particular market and region; the provision of refrigerated vaccines for immunisation of children in Sub-Saharan Africa [The 'Cold Chain System' of the World Health Organisation (WHO)]. A premise was that countries were expending considerable sums in purchasing these products from mainly western countries; thereby foregoing employment and using up valuable foreign exchange reserves.

A conclusion of the field research was that there was *already* adequate manufacturing capacity and expertise to compete in this sector and indeed the local firms were already producing superior/appropriate products in a related product sector (domestic refrigerators), in terms of robustness for local conditions. However investment in product design/engineering was one important 'missing link' in producing the more specialised Cold Chain refrigerators. The imported products passed the strict performance and reliability testing required by the WHO. A broader finding was that countries need to invest in design in order to compete in increasingly open international markets, and that such 'micro factors' are crucially important for economists and policy makers advising macroeconomic reform.

1. Research and Development, Innovation, New Product Development and Product Design - Definitions

1.1 Research and development

Research and development, innovation, new product development and product design are often used interchangeably, but they each have quite distinct meanings.

Research and Development (R&D) is the process of creating new knowledge about products or processes. R&D is defined in the Frascati Manual written for the OECD as (OECD, 1981 cited in Walsh et. al, 1992: 20)

> *"Research and experimental development, (R&D) comprise creative work undertaken on a systematic basis in order to increase the stock of knowledge... and the use of this stock of knowledge to devise...new materials, products, or devices...new processes systems and services, or ...improving substantially those already produced or installed"*

1.2 Innovation

Technical or industrial innovation is used to describe a new breakthrough in a process or production technique or a novel product and it is used widely by economists. Innovation is defined by Walsh et. al. (1992: 16) as:

> *"The whole activity from invention (the discovery of a new device, product, process or system) to the point of first commercial or social use.."*

Innovation, therefore can involve the exploitation of a new market opportunity, or on the other hand, the development and marketing of a technical invention; however it usually involves a combination of both since many inventions have no market demand and so do not constitute an innovation.

1.3 New product development

New product development is a term often used by the management and marketing department of firms. It describes the process of changing the form, components, materials, marketing or packaging of a product, and it differs from innovation in that it does not usually involve invention. It is defined by Walsh et. al (1992: 16) as:

> *"the process that transforms technical ideas or market needs and opportunities into a new product launched on to the market"*

1.4 Design

A broad definition of design is given by Caldecote (1979) cited in Walsh et. al (1992: 18) as:

> *"The process of converting an idea into information from which a new product can be made"*

The OECD (1982) cited in Walsh et. al. (1992: 18) defines design more precisely as:

> *"Design is the very core of innovation, the moment when a new object is imagined, devised and shaped in prototype form."*

Different cultures perceive and see various roles for design. For instance the UK is seen as having a more analytical and marketing approach to design, whereas in Japan, design is more concerned with what 'could be'; therefore in Japan design is seen as being more of a creative process (Evans, 1986).

Design covers a broad spectrum of activities: architecture, fashion design, craft work, product design, graphics and typography.

1.5 Product design

Product design is often misunderstood as a concept. It is commonly seen, even by managers of companies, as the process of making products look aesthetically pleasing or stylish. Most product designers understand product design to mean much more than this. Product design is a multi-disciplinary process which usually involves market and technological research, concept design, prototype development, final product development and testing as well as post production refinement. Product Design is defined by Walsh et al (1992: 18) as:

> *"The activity in which ideas and needs are given physical form, initially as solution concepts and then as a specific configuration or arrangement of elements, materials and components"*

Product design does not usually imply the utilisation of new technologies to create novel products. Typically, it entails the refinement or upgrading of existing designs, to improve functionality, performance or appeal. Another goal is to lower the cost of manufacture for competitive advantage. New technologies may be used in existing/established products, for example in using microprocessors to control and improve energy efficiency and water use in washing machines. Product Design can also involve adapting products for particular markets or environments.

Product design can be sub-divided into different types; mechanical component design, electronic design, aesthetic design, industrial design, engineering design and graphic design. While product design is carried out in almost all industries, it is not necessarily done in a systematic fashion by professional designers. In many instances design is carried out by a draughts person, production manager or toolperson. This would be typical of companies in developing countries and smaller companies in industrialised countries. This is what Gorb and Dumas term "Silent Design" (Gorb and Dumas, 1987). These silent designers may have no training in design. Design activity may consist of copying and adapting existing products or "Sketching on the back of a cigarette packet". (Walsh et. al. 1992: 22) Christopher Freeman identifies four kinds of design activity (Freeman, 1983: cited in Walsh et. al: 1992: 22):

- Experimental design: the design of prototypes and pilot plant leading to the preparation of production drawings for the commercial introduction of a new product or process
- Routine design engineering: the adaptation of existing technology to specific applications (typical of the design work done by many engineering firms when installing new plant or equipment)
- Fashion design: aesthetic and stylistic design of items ranging from textiles and shoes to chairs, car bodies and buildings (this kind of design may result in novel forms, shapes or decorations, but often involves no technical change at all)
- Design management: the planning and co-ordinating activity necessary to create, make or launch a new product on the market.

To summarise, there is considerable overlap between R&D, innovation, new product development and product design, however product design is much more widespread in industry than R&D (Walsh et al 1992:19). Pure research is usually carried in universities or for example, in agricultural research centres. Further R&D is carried out by some companies, typically in industries such as chemicals, pharmaceuticals, and aerospace. Innovation involves a new invention being matched with a market need. New product development is the term given to the process of bringing new or updated products to the market. Product design describes the creative process in researching markets, innovations and needs, then transforming ideas into products for particular markets.

2. Product Design, Innovation and Competitiveness

2.1 Microeconomic factors and design (the commercial role of design)

Product Design is one of the most important non-price factors which determines the success of a product. The role of product design changes throughout the life-cycle of a product. In the initial product development stage, the role of design is to create a marketable product from an innovation. The product may create a need where none existed before, (for example when the Sony Walkman was introduced) or quite different products may be competing with others in the same market (for example trams, cars and buses compete for urban transport). As the product life cycle matures, more competitors enter the market and the chief role of design is in product differentiation; through quality, appearance, performance, ease of use, reliability, reparability and so on (Walsh et. al. 1992: 32,82).

The importance of design as a non-price factor and the role of design in determining the production and running costs of a product lies in the theory that:

- A purchaser will chose a better designed, higher quality product when given the choice of two products of similar price.
- A purchaser will chose the cheaper of two products of similar design and quality.

In reality, purchaser choice will also be influenced by various other non-price factors such as availability, advertising, company image, and ideology (for example, nationally produced or environmentally friendly products) (Walsh et. Al, 1992: 65). In addition, price is often regarded as an indication of quality (Uganwa and Baker, 1989). Finally, purchasers can also chose between a product or a service (for example a washing machine or a laundry).

A number of studies (Pavit, 1980; Patel and Pavit, 1987; NEDO, 1979) have shown that innovativeness and technical sophistication are the non-price factors which most determine competitive success in international markets.

While product design is generally considered to be a non-price factor it also important to consider the influence of design upon product price. Product design effects the cost of production through the choice and use of materials and how the product is assembled (known as Design for Manufacture). Design also influences after-sales maintenance and running costs (which is more important for some types of products such as heating systems). Running costs are often calculated as being integral to the price of a product in purchasers decisions. Therefore it is simplistic to view design as purely a non-price factor (Walsh et al: 80-82).

In the UK, studies of the return of investment in design have been carried out by the Design Innovation Group of Open University and Manchester Institute of Science and Technology. One study showed that 'Design Conscious Firms' had a three per cent higher return on capital, one per cent higher profit margin, 28 per cent higher Turnover growth and a seven per cent higher capital growth than a representative sample. (Walsh et al: 1992, 79).

2.2 Macroeconomic factors and design

In industrialised countries, the link between design of products and industrial competitiveness has increasingly been acknowledged by economists and policy makers as well as by designers themselves.

In the UK, two important reports stimulated debate into the important role of design in competitiveness: the Corfield Report on Product Design (NEDO, 1979) and the Finniston Report, 'Engineering our Future' (Finniston, 1980). The reports suggested that Britain was declining industrially through loss of market share to other countries, especially Germany and Japan, both of which were renowned for the high quality and design of their products. The reports pointed to a cause being the UK's relative lack of investment in Research and Development and Product Design. Walsh et. al. (1992: 4) summarises the main findings of these reports:

> *Since the Second World War, and particularly since the late 1950s, the creation and manufacture of well-designed products, across the whole spectrum of innovation, have become essential to the success both of individual companies and national economies...our research has shown that those firms that invest*

resources and professional expertise in product and industrial design in both traditional and new industries have been commercially more successful than firms that pay less attention to these aspects of design.

Such has been the concern in the UK with the country's decline in the share of the world's manufactured products, that during the 1980s, the Conservative government significantly departed from their policy of reducing public spending when they funded a new initiative to directly subsidise product design within firms (the Support for Design Scheme). Margaret Thatcher (1992) cited in Walsh et. al. (1992: 69) wrote of the importance of product design:

There are many ingredients for success in the market-place. But I am convinced that British industry will never compete if it forgets the importance of good design. By 'design' I do not just mean 'appearance'. I mean all the engineering and industrial design that goes into a product from the idea stage to the production stage, and which is so important in ensuring that it works, that it is reliable, that it is good value and that it looks good. In short it is good design which makes people buy products and which gives products a good name. It is essential to the future of our industry.

These reports and government initiatives have been reflected in other reports relating to design in Japan, Germany, France, UK, Scandinavia.

According to Braunerhjelm and Fors, comparative advantage can be regarded from two perspectives, static or dynamic. In this analysis, static comparative advantage includes the fixed factors of production such as physical capital, labour, human capital, labour skill, land and natural resources. Dynamic comparative advantage is the ability to upgrade skills, adopt new technologies, introduce innovative products and production techniques and the transfer of these technologies between companies in a country. Therefore, goods competing on price, compete on a static comparative advantage whereas goods which are of higher value added, more technically sophisticated and differentiated, require that dynamic comparative advantage be present (Braunerhjelm and Fors, 1994: 7). Thus product design, as a process, is a factor of dynamic comparative advantage. Braunerhjelm makes two important points regarding dynamic comparative advantage; firstly, with dynamic

comparative advantage it is more difficult to predict which firms will succeed, since success depends on individual companies internal capacity to innovate and adapt. Secondly, in an open international economy, it will be more difficult to predict winners (Braunerhjelm and Fors, 1994: 6-7).

2.3 Design, Competitiveness and Developing Countries

While in industrialised countries, product design has being seen as increasingly (but often only recently) important to international competitiveness, in developing countries the same has not been true (Vijoen, 1997: 4-5). It is only recently that the design of products has been seen as an important factor in competitiveness. There are a number of reasons why design was not seen as being important in the past:

- As outlined in section 2 above, product design was often perceived as an exercise in aesthetics or fashion, as opposed to being a complex synthesis of market needs, creativity, technology, cultural and environmental appropriateness, ergonomics, and manufacturing. Therefore, product design was seen as being irrelevant to developing countries
- Since people in developing countries have lower per capita incomes, it is assumed that they are not able to afford "well designed" products. This assumption ignores the fact that product design can reduce the cost of products or make products more durable and of better quality. Therefore products would be 'well designed' if they were appropriate to their market
- Up until the 1970s most developing countries had a policy of Import Substitution Industrialisation. This had the effect of closing off markets to better designed imported products. Along side this, there has always been a high degree of state involvement in manufacturing in developing countries. This has been attributed to the lack of a middle classe capable of leading industrial development (Chandra, 1992: 62). State run enterprises have a tendency to be more production focused than marketing oriented. Monopoly enterprises do not have as much of an incentive to innovate.

Product Design is now seen as being relevant to developing countries since:

- World Bank and developing country policy has favoured the opening up of markets through tariff reduction. This has exposed local producers to cheaper and better desiged products, so firms are being challenged on both domestic and export markets
- Particularly in industrialised countries, product characteristics such as design, frequency of new product introduction and quality are becoming increasingly important. Price competitiveness (while still important) is diminishing in priority (Kaplinsky, 1994: 13) Industrial country markets are the main source of export expansion for DCs
- The newly industrialised countries of South East Asia have successfully used product design to produce competitive products for world markets
- There are opportunities for developing countries to design products which are appropriate to their own markets. Domestic producers have the advantage of knowledge of their local market and environment, as well as proximity to customers.

Van Dijk (1990: 214) has written about the increasing importance of non-price factors in the context of developing countries:

> *"Theories concerning industrialisation usually assume that industrial products can be absorbed by the world market if prices are low enough. This view is too simple. Marketing Channels, quantities produced, sensitivity to changes in consumer taste, etc. have become so important that small countries cannot easily export industrial products, not even if they have a comparative advantage."*

While, product design has had marginal importance in the industrial policies of developing countries in the past, new moves are being made to promote its use as a development tool:

- The European Union has funded research into the use of product design in various countries. Internationally, conferences have been organised to promote product design, notably: in 1997 the International Council for the

Societies of Industrial Design (ICSID) held a conference in Pretoria to address the subject of "Industrial Design Education for Developing Countries".

- The World Bank (1993: 1) has begun stressing the need to focus on the competitive capacity of individual firms in the overall development of the industrial sector:

> *Research by Bank consultants Martin Bell and Keith Pavitt shows that private firms, sometimes with public support, make a far greater contribution to the pace of change than public institutions. [1] As individual firms increase their efforts to initiate and manage change, they need to invest in research and development laboratories, design offices, and production engineering studies. Policy makers seeking quicker technological change need to take the needs of private firms into account.*

In a case study of Mauritus, the world bank has highlighted another important role of design. In Mauritius, there has been downward pressure on wages since companies profit margins have been reduced by international competition after markets were liberalised. The bank suggests that investment in product design will upgrade products, increase workforce productivity thereby maintain or increase both profit margins and wage rates (WB, 1994: 1).

> *The experience of Asian NIEs shows that developing local design capabilities can play an important role in helping firms increase value-added and sustain competitiveness despite high labor costs.*

Japan, is cited by Freeman (1987: 67) cited in Walsh et. al. (1992) as being a country where product design has played a crucial role:

> *...Japan in fact recognised in its post-war reconstruction programme the need for advanced industries capable of supplying products of high quality and good design, incorporating the latest technology and materials. In post-war Japan, there was actually an explicit struggle between the traditional economists who argued that Japan should concentrate on sectors like textiles, where it had a comparative advantage (cheap labour), and the majority of economists in the Ministry of*

International Trade and Industry who argued for the identification of key 'leading edge' technologies and strategies for Japan to achieve in them an international competitive position in the medium term'

This quote also touches on the important notion that comparative advantage is not unchangeable. The role of product design in the Newly Industrialised Countries of South East Asia has had an effect on policy thinking in developing countries. Singapore, for instance, has invested heavily in the product design with the establishment of the Singapore Design Centre to promote design in Singaporean industry.

In developing industrial strategies, the role of product design must be seen as an important element for success. Developing countries need to invest in improving the quality and design of their products in order to remain internationally competitive. There exists the opportunity to create new employment and provide products which meet the needs of people in developing countries through product design. Therefore capacity needs to be developed in order to educate a body of designers who understand the role and process of design in the development of individual companies' products for both domestic and export markets.

4. Human Resources for Design

4.1 Organisation of design within a firm

Companies evolve from small businesses through growth, mergers, and acquisitions into their current structure. How design is organised within a firm is a consequence of this development (Walsh et. al. 1992: 119). For example, in a small expanding firm, the design and development of new products might be the prerogative of the original founder/manager, whereas in a large transnational firm, design may be carried out in various subsidiary development centres which were established before the TNC purchased these subsidiaries.

Historically, the function of design within firms was a result of improvements introduced by people working directly with the production process; engineers and craftspeople. In the 19th century, the "U-form" structure of firms was developed. In the U-form structure, firms are divided into functional departments; finance, production, marketing and sales, quality and so on. This was a response to the expansion of firms, whereby management was devolved to each department. Starting in the chemical engineering industry in the 19th century, research and development departments were established in response to the need for autonomy from universities and other research agencies in the development of new technologies. Eventually, research and development departments were established in other industries. In engineering, the application of scientific principles and laws (for example in thermodynamics) increasingly meant that the design of many categories of products became more technologically sophisticated. As a result, design and product innovation became reliant on specialist skills and design became associated with research and development activities (Walsh et. al. 1992: 122; Kaplinsky 1994: 29).

In a study of British Industry in the 1980s, the location of design within companies was determined for a number of British and foreign owned firms operating in the UK. The results, shown in Table 3.1 below, show in per centage terms, which department or person was responsible for design and product development.

Table 3.1 Responsibility for design and development in UK and foreign owned firms in the UK

Department of person responsible	% of design activities
Managing Director	24
Marketing Sales	8
R & D Dept	18
Production/engineering	2
Design/design and development	26
Outside Consultancy	4
Interdepartmental group	18

Walsh, V; Roy, R; Bruce, M. Potter S. 1992 **Winning by Design: Technology, Product Design and International Competitiveness**, Oxford, Blackwell: Table 4.1 p123

The table shows, that within UK firms, design is carried out within a variety of departments and by a variety of personnel. In contrast, in successful foreign owned firms operating in the UK, 55 per cent of design and development is carried out by an interdepartmental/ interdisciplinary group. The greater inter-departmental use of personnel for design was particularly marked among Japanese owned firms who also employ greater numbers of staff in research, design and development. One Japanese electronics firm employed 5,000 scientists, engineers and designers (25 per cent of its staff) whereas in UK firms, between, 3 and 5 per cent of staff were employed in these areas (higher in electronics firms) (Walsh et. al, 1992: 125). The Japanese approach to design and development is part of the new Japanese management paradigm which has being adopted by many manufacturers throughout the world.

In general, there is a great variance in the number of people employed in design and in the personnel and departments responsible for design, even in firms and industries producing the same goods. As outlined before, this is often due to the historical evolution of a firm; it is also a consequence of whether firms are market leaders or mainly copy other firms and also largely dependent on the type of product(s) being produced. Therefore the role of design in firms is extremely ambivalent, especially when compared to other activities such as marketing or finance. This means that managers of firms must be very clear about their design policy.

4.2 Management of design

In the management of design, it is critical that management defines product design and development policy. This will involve a clear understanding by management of future market trends and the identification and definition of product development goals; which products need to be developed, what competition is likely to be faced and what resources will be needed (Walsh et. al. 1992: 117).

As a consequence of the fact that design in companies is often carried out by a wide range of personnel/departments, the management of human resources for design is extremely important. The Corfield Report (regarding the UK design industry) recommended that there should be a design director on the board in manufacturing companies (Walsh et al. 1992: 130). Walsh, however, found that it is more important to have a specific individual or group within the firm made responsible for design. A second recommendation, was that all the design skills in a firm be utilised fully; whether by professional engineers and designers or by "silent designers" (See section 1.5 above). The design function of staff should be explicitly defined and staff should receive appropriate training (Walsh et. al, 1992: 136).

Finally, the management of a firm needs to decide how much of the company's finances will be spent on design. The financing of design must be carefully monitored and evaluated, since the allocation of resources to design is essentially an investment decision. (Walsh et. al, 1992: 116)

4.3 Japanese management techniques

Since the 1960s, Japanese traded goods have emerged from relative obscurity to become extremely successful in world markets. Originally, it was thought that the rapid adoption of automated technologies was responsible. However it became clear, that the development of a new production system was of primary importance in making Japanese goods more successful (Kaplinsky, 1994: 34).

The emergence of Japanese management techniques in the last two decades, has had a significant effect on how production is organised in manufacturing companies

world-wide. This method of management has a profound influence on how products are designed produced and modified, since they rely on a system of *"kaizen"* or continuous improvement. Japanese management techniques are being increasingly adopted by American and European firms. Raphael Kaplinsky has conducted research into the diffusion of Japanese management techniques to Less Developed Countries and concluded that Japanese management techniques may be highly appropriate for developed countries (Kaplinsky, 1994: 34).

The Japanese management system is based on a replacement of the mass production system with a flexible specialisation system. The mass production system emerged as the dominant mode of production in the last century through the realisation of economies of scale through standardisation of components and processes. The system has become increasingly obsolete due to the increasing volatility of markets which increases the cost of large inventories and a greater demand for differentiated products. A further factor is that firms were traditionally seeking to reduce labour costs through the 'dumbing down' of the labour force and the introduction of automation. This was causing labour unrest, whereas in Japan the emphasis was in using labour as a resource to be maximised (Kaplinsky, 1994: 12-13).

The basis of the new Japanese paradigm is in the reduction of product inventories through the imposition of the 'Just in Time' system. The system is based on the following eight points:

- Reducing inventories in order to 'pull' production through the factory [In contrast, in a mass production system, production is maximised in order to optimise machine use]
- Making quality a responsibility of every worker at every stage of production - in order to reduce reworking and reduce inventories
- Having a cellular production system rather than a linear production system
- Reducing batch size
- Reducing the changeover time for machinery through a flexible labour system whereby workers are given the responsibility of intervening in production and are trained in multiple tasks

- Optimisation on a system wide basis rather than at an individual plant, worker or machine level
- Closer co-operation between the company and its suppliers.
- The endogenisation of change: making change continuous.

A feature of Japanese management techniques is that productivity increases are only significant when *all* these changes are introduced, since many of the changes are interdependent and interrelated (Kaplinsky, 1994: 19 - 34).

In particular, the last point, the endogenisation of change, makes firms adopting these techniques much more inclined to focus on design and incremental product improvement. Design changes can be much more readily integrated into the production system, changes in customer/market demand can be responded to more rapidly and it is easier for staff to provide an input into the design process.

Japanese management techniques are of great significance to LDCs because unlike the transfer of conventional production systems, significant increase in productivity is achieved through a change of organisation, rather than through investment in costly machinery and capital intensive technology. Therefore, Japanese management techniques are considered to be much more technologically appropriate to more labour intensive conditions which are typical of developing country production. The techniques also have a low adoption cost, do not require foreign exchange, make firms in LDCs more world market oriented and more insulated from exogenous shocks. (Kaplinsky, 1994: 6)

In Zimbabwe, Japanese management techniques have been introduced to more than 50 manufacturing companies through the Price Waterhouse management consultancy firm which markets the organisational procedures of the Japanese manufacturing firm Kawasaki. The results in Zimbabwe were mixed, from improper implementation in some firms, to significant gains in productivity in others (Kaplinsky, 1994: 162).

4.5 Design skills

The design of a product requires the skills of a wide variety of personnel: Mechanical Engineers, Production Engineers/Production Managers; Product Designer/Industrial Designers, Scientists, Electrical engineers, Marketing Staff and Production Personnel. Which personnel are required for the design of a particular product is dependent on the type of product and whether it is an improvement on an existing product or a new product.

According to Walsh et al (1992: 50) and Cross (1989: 16), industrial and product designers are required to have creative, analytical and technical skills including:

- **Tacit knowledge** - implicit and internalised knowledge derived from experience, about the way in which systems or products operate.
- **Visual imagination** - the ability to imagine objects which do not exist - new and novel mechanisms, configurations of components and product forms. Designers need to look at things in new ways in order to come up with new solutions.
- **Idea representation** - the ability to communicate ideas through drawings, sketches and models.
- **Research skills** - the ability to source and assimilate vast amounts of information and ascertain what is most important.
- **Communication skills** - the ability to listen to a variety of different people - customers, users, management, other designers and marketing and production staff.

(Walsh et. al, 1992: 50; Cross, 1989: 16)

In addition, engineering designers will have knowledge in engineering subjects: physics mathematics, economics, materials, thermodynamics, fluid mechanics, applied mechanics, Computer Aided Design, design for economic manufacture, design evaluation.

Generally, designers will also have knowledge of ergonomics, presentation techniques, economics, design process, time and project management and various

computer programs. Often designers require a working knowledge of electronics in order to work with electronic engineers or incorporate electronic devices into products. A practical knowledge of production techniques and production processes such as welding, fitting, machining, woodwork/carpentry is also necessary for designers to produce products which can be feasibly produced (University of Glasgow/ Glasgow School of Art, 1992).

5. The Design Process

In general, the formal process of design is remarkably similar across a range of products and design disciplines from architecture to product design to fashion. According to Pugh (1991: 6) Walsh et. al. (1992: 52) and Cross (1989: 21) the product design process generally involves the following steps:

- Examination of market needs
- Problem/need analysis and the Design Brief
- Product Design Specification
- Concept development and prototyping
- Embodiment design
- Detailed design
- Design for manufacture
- Design review and evaluation
- Post production design and improvement

Examination of market needs

Market-led design is the process of transforming customers needs into saleable products. The customers can be people, institutions or other companies. The needs of customers are often multiple and complex. Market-led design contrasts with technology-led design, in which the driving force behind product development is a new technology, and production-led, where design is based on the production equipment available.

The main aim of market-led design is to produce products which are suited to the

needs of their users and to avoid the costly mistake of designing a product for which there is no demand. Establishing the needs of customers is the most difficult aspect of market led design, since customers do not always know what they want. Knowledge about markets comes from a wide variety of sources: legislation, patents, copyrights, reports, proceedings and trade journals, competitor products, statistical data, and through surveys and interviews with customers and users (Pugh, 1991: 29-43).

Problem/need analysis and the design brief

The problem/ need analysis stage of the design process is where the designer, or marketing department analyses and collects information about existing products and markets, and the need or problem which the product will be aimed at satisfying or solving.

The design brief is a formal document which describes succinctly what is to be designed and for which target markets. It emerges from an analysis of the need or problem. In a company, the brief is usually drawn up by the marketing department or management. The purpose of the brief is to make it clear to the designer, exactly what it is they are designing. The British Standards Association (1988) cited in Walsh et. al. (1992: 198) describe the importance of the design brief in the draft British Standard on Product Design BS7000:

> *The importance of the design brief cannot be over-emphasised. An inadequate design brief is a dangerous document: it may mean that management does not know what it wants, but it certainly means that the designer is misinformed about what is required....it is regrettable that many designers are obliged to work to briefs that are inadequate - or are even non existent.*

In the production of successful designs, it is essential that the requirements of customers are fully researched. At this stage a plan is usually drawn up to establish the time-scale for the design process and the personnel and resources which will be utilised.

Product Design Specification (PDS)

The Product Design Specification (PDS) is a detailed document which sets out the marketing and technical parameters of a product. Marketing specifications describe the target market, price, image and performance requirements of the product. A consideration basic to all good design is the factor of cost. The technical specification is more detailed and describes such aspects of the product as: what the product must do, weight, size, power consumption, location and user environment, ease of use, standards applicable, cost requirements, materials, manufacture, reliability, maintenance, packaging and how the product will be transported: from the factory and in use. The document sets out the parameters within which the product is designed. The document does not limit the design solution, so for instance, the material specification might be; "non-toxic" or of a certain strength/weight ratio - thus ruling out some materials but not excluding others. The document is usually drawn up by several departments within a firm and includes the designer(s) (Pugh, 1990: 44-66).

Concept development

The concept development stage of product design is when the designer develops design concepts and solutions through drawings and mock-ups. The solutions should comply to the requirements of the Product Design Specification. The process of coming up with design concepts will vary between designers and product types. In general, a designer will come up with solutions from the following sources:

- Existing products - produced by the company or competitors
- Existing or new technologies - which are applied or combined in new ways
- From current ideas and trends within design - exhibitions, journals and interaction with other designers and engineers. From analysis of patents and trade literature
- Through creative problem solving and application of analytical theories
- Through suggestions from customers and product users as well as the designers own experience (Walsh et al, 1992: 207).

Embodiment and detailed design

This leads on to evaluation of the best solutions which are carried on to the embodiment stage. During the embodiment stage, one or more prototypes are produced.

The detailed design stage involves taking the best design solution and optimising every component and aspect of its design. At this stage, market testing is usually carried out in order to find out if there are any design faults or possibilities for improvement.

Design for manufacture, maintenance and reliability

Design for manufacture involves the consideration of how parts and components will be produced and assembled. It is essential that the designer works along with the production staff and is fully aware of the production limitations. The primary goal is to reduce costs but design for manufacture may also be targeted at improving quality or minimising environmental impact during the production process. Design for manufacture has particular significance in the context of developing countries. Many firms in LDCs do not have the resources with which to regularly update plant and equipment so it may be preferable to design around the limitations of existing equipment and utilise (relatively cheaper) labour rather than investing in expensive (possibly imported) plant.

Design for manufacture is closely related to design for reliability and reparability. Designing for reliability involves the determination of the mode failures of a product - how the product is likely to break down. Reliability and durability can be improved by simplifying complex systems (which are usually less reliable) or by changing the design or specification of parts which are likely to fail. Some parts are actually designed to fail or be expendable, but are easily replaceable. This is to avoid having to replace a more expensive component (For example the light bulbs need replacing rather than entire light fittings).

Designing for maintenance and repair requires that the designer take into account how the product will be serviced. The designer considers who will be repairing the

product - whether the user or a repair-person, which components are likely to require cleaning or replacement and how access can be gained to these components. This aspect of design is particularly important in LDCs since there may not be a sufficient network of trained repair people—or conversely—maintenance and repair shops may be more concerned about the ability to use standardised parts. Issues of reliability and repair are closely linked to the broader issue of sustainable consumption and the associated political and social choices of appropriate legislation and regulation. This is explored in greater depth in section 8.2.

Design evaluation and review

Design evaluation is a function which is carried out at various stages of the design process. Its purpose is to check that the design solution is in accordance with the original design objectives. The PDS provides the criteria against which the design can be evaluated. Design evaluation is used to eliminate those solutions which do not satisfy the criteria and can also provide a means of deciding between different design solutions. One method of systematically evaluating design solutions is to establish a list of criteria, organised in order of importance. For example: different design solutions are evaluated against the criteria 'that a solution is less costly than an existing product' (Pugh,1991: 74; 77).

Design evaluation may be carried out after the initial concept stage and again after the detailed design stage and finally, before the design is launched on the market. Often design evaluation is carried out by a group of people (for example a team representing different departments in a firm). Group evaluation provides a more subjective means for looking at solutions and may generate new ideas. During the design process it is important that pertinent design decisions, drawings, ideas, results of testing and evaluation are recorded. This is to aid future product development.

The design review is a more general evaluation of the design process - to evaluate whether the design process has been successful and has kept within budget and time-scale. This information is valuable in estimating resources required for future product development.

Post production design and improvement

Post production design and improvement is carried out through feed-back from sales staff, resellers, and the users of a product. The purpose is to correct faults and instigate improvements which were overlooked in the design of the product.

6. Product Design and Appropriate Technology

The concept of "Appropriate Technology" (AT)—defined below—was first made popular by the writer E.F. Schumacher in the book "Small is Beautiful" in 1973. The concept has been closely associated with Intermediate Technology group, an international Development NGO. The concept of AT is now widely accepted by such institutions as the World Bank and Food and Agricultural Organisation of the United Nations (FAO) and many governments. Notably, during the 1980s President Julius Nyerere of Tanzania tried to promote AT. Nevertheless, there is much debate and criticism about the concept and its application. Appropriate Technology (AT) is defined by Water Aid (1996: 7) as:

> *An Appropriate Technology is one which meets a locally defined need using locally available materials and resources, which are themselves managed in a sustainable manner.*

A more elaborate definition is given by Niklas Sieber (1996: 7) of the International Forum for Rural Transport and Development as:

> *An Appropriate Technology is one which is designed to optimally satisfy demands by taking into account the economic and social situation of its users, and the natural environment of its operation. In comparison with conventional technologies, AT is affordable by a large number of users, decreases social inequalities, and creates environmental sustainability. AT will be vital in the next Millennium because it helps to increase the welfare of the South without massively degrading the natural environment.*

From the above definitions it can be seen that a great deal is demanded of an

"Appropriate Technology". H.G.W. Pierson of Spain (1996: 7) has a contradictory view:

> *The name Appropriate Technology is basically a nonsense, which should never have been embraced in the first place....most of the practitioners of AT assume that the very appropriateness of their technology makes them priests of some higher order, and thus not bound by the normal considerations of cause and effect, market forces, and pragmatism. Perhaps it is useful to remember that weapons of mass destruction are extremely appropriate for their purpose.*

In the context of design, however, the concept of appropriate technology is much clearer. This is because, 'good' product design is concerned with fulfilling defined human needs within a wide range of criteria. Therefore, product design should always be appropriate. It should be clear from the description of the design process in Section 5 above, that the designer must consider many of the factors which are advocated by those promoting AT such as cost, ease of use, reparability and design for manufacture. Therefore, investment in product design in LDCs ought to lead to more appropriate technology.

6.1 Appropriate production technology and appropriate products

The term Appropriate Technology often covers two separate and quite distinct terms, namely, Appropriate Production Technologies and Appropriate Products. Appropriate production technologies usually refer to those that are labour intensive. Kirkpatrick (1984: 216) describes why labour intensive technologies are suited to LDCs:

> *Given the relatively labour abundant/ capital-scarce resource endowment of most LDCs and assuming that the market prices of the factors of production reflect social opportunity costs, it is argued that LDCs should select technologies that utilise most intensively their relatively abundant factor (labour) and economise on the scarce factor (capital).*

The Committee for Economic Development (CED) argues that governments in LDCs should avoid policies which encourage the purchase of capital intensive production. Over-valued exchange rates or concessionary loans for the purchase of machinery

and equipment should be avoided (CED, 1981: 9).

With regard to product design and appropriate production techniques, the designer has a choice of designing products for the available production facilities and labour skills, or designing products which will require the firm to invest in more sophisticated machinery. The choice of the designer is usually not as clear cut as this. The next section describes a case study involving appropriate production techniques.

Appropriate products, can be loosely defined as products which are designed for their intended markets. In LDCs many products on the market were designed or copied from designs intended for Industrialised country markets. These markets have very different characteristics to LDC markets. The CED describes how this mismatch occurs when technology is transferred through Transnational Corporations (TNCs) (CED, 1981: 51).

> *With respect to products, the concern is that they may be too sophisticated, too highly designed, and too elaborately packaged to meet the needs of most of the people in poor countries. Such products which reflect the tastes and standards of the home country, are often said to cater largely to the consumption demands of the elite in the host country.*

Weiss (1988: 240) however, argues that technology transfer to LDCs results in significant technology adaptation and can lead to technological innovation and learning:

> *Even where technology is received from abroad through formal mechanisms there is evidence from a range of countries that significant efforts have been made to adapt it to the prevailing economic conditions of the recipient countries.....their successful introduction in some industries has led to the development of new products or processes, so that relatively simple technical change arising from production experience using imported technology can contribute to more complex higher state technical change.*

In designing appropriate products either within LDCs or for LDCs, designers must focus on the following design parameters (Pugh: 1990, 48-64):

- The cost of products - whether the products will be affordable to the people who will use them
- Ease of use - are users familiar with the technology (Whether users are literate; if so, are instructions available in the users language)
- The product environment—the conditions under which products will be used—including transportion, storage, continuity in power source, dirt, ambient temperature, handling.
- Maintenance and repair considerations - availability and cost of spare parts and qualified maintenance personnel, ease of repair, mode of failure .
- Social/cultural/gender factors—how a product fits in with local social, cultural and gender conditions—who will use it, how will it be used, if it will replace or compliment existing activities, how will it look.

All of these are specifications which are included in the PDS. Therefore, as emphasised in the previous section, the systemic application of the product design process leads to the design of more appropriate products.

6.2 Appropriate Technology – A Case Study

In 1997, Pierre Yves-Panis, a Belgian Industrial Designer working in Harare, set up a design co-operative (Design Co-operation) in the Mbare Siya-So production site in Harare. The aim was to improve the incomes of furniture makers in the sector. He achieved this through designing higher value added products, which were more suited to available markets and the existing production environment. Yves-Panis designed a new range of furniture products which drew on the strengths of the craftsmen, the working conditions and the available markets. Previously, wire framed tables and chairs were being produced by the craftsmen, but profit margins were being eroded due to the importation of mass produced furniture from South Africa and elsewhere. New attractive designs were produced based on:

- The new products were be aimed at a more sophisticated market
- They were be designed to be produced with existing equipment and under the prevailing work conditions

- To be produced from available materials
- They were be of uniform quality
- They were be profitable
-

In an interview with Yves-Panis in the summer of 1997, he stated that the new designs took into account of the craftsmen's skills - for example, simpler joints were used, straight pieces of wood and slats replaced one-piece components, wood oils instead of varnish produced a better quality finish at a cheaper price.

The result, according to Yves-Panis (1997) was as follows:

> *"The project proceeded slowly with artisans reluctant to change their practices until they could ascertain the benefits of innovation. Eventually, a range of products were established which became very successful and demand now outstrips supply. Artisans also began to add their own designs and innovations to the furniture which they were producing."*

7. Product Design, Industrialisation and the Environment

In the last twenty-thirty years environmental issues have come to the forefront of the international political agenda. Environmental problems range from the macro level - deforestation, global warming, holes in the ozone layer, deforestation, natural resource depletion, and loss of biological diversity; to the micro level - pollution of local environments, toxins in foodstuffs and changing health and disease patterns. Some of these environmental problems are more associated with agriculture than industrialisation, or the 'industrialisation' of agriculture, by which is meant the application of modern technological processes to farming. In addition, environmental problems are not necessarily a function of industrial or agricultural processes per se, but rather the replication of these processes on a world-wide level, in the context of rapidly expanding consumption and rising population levels. Environmental problems are also a consequence of changing leisure and transport activities (for example water-sports, air transport) which are linked to increased wealth and are *ipso de facto* associated with industrialisation (Keating, 1993).

There is much uncertainty and debate about the cause, result and consequences of

particular environmental changes. For example Wilfred Beckerman, a former consultant with the World Bank, believes that estimates of sea level rise over the next one hundred years (due to global warning) have been constantly revised downwards. If sea levels did rise appreciably, technology could be employed to defend areas of high population density. Even for countries like Bangladesh, Beckerman believes that the cost of preventative 'draconian' measures in forgoing economic growth and reducing CO2 emissions would be far greater than dealing with the consequences of sea level rise (Beckerman, 1992: 485).

Because of increased concern about environmental issues, particularly in industrialised countries, the United Nations World Commission on Environment and Development commissioned the Bruntland report which was published in 1987. The report contributed to the Earth Summit in 1992 from which emerged Agenda 21, a global plan of action on environmental problems. The Bruntland report has as a key concept that economic growth *is* compatible with 'Sustainable Development'. In the report, cited in Smith, (1992: 282) Sustainable Development is defined as:

> *"development that meets the needs of the present without compromising the ability of future generations to meet those needs"*

The World Bank uses a different term: Environmentally Sustainable Development (ESD) to differentiate from development which is economically self perpetuating (sustainable development). Brundtland cited in Smith et. al. (1992: 277) deals with the apparent conflict between economic growth, resource use and the environment. She states that:

> *"it is both futile and indeed an insult to the poor to tell them that they must remain in poverty to protect the environment."*

Williams questions the idea that industrial development and human well-being is commensurate with environmental problems; rather the current form of industrialisation/development is destructive. Williams (1982) cited in Smith et. al (1992: 281) states:

> *"We shall get nowhere in thinking about these problems [of industrial development*

and environmental impact] if we think that it is only the distinctive forms of modern industrial production that represent the problems of living well and sensibly on the earth."

There many opinions as to how sustainable development is to be achieved (if at all). However Smith identifies three distinct approaches: the Structuralist, the Neo Liberal and the Environmentalist.

The Structuralist approach emphasises inequality between North and South. Structuralists believe there are many contradictions in the Brundt report and that the global capitalist system is unable to accommodate the changes required to achieve sustainability. Northern countries are culturally biased in their view of what sustainability means. Sustainability is not possible without radical structural transformation (Smith, 1992: 284).

The neo-liberal approach identifies market mechanisms as the most efficient means to efficiently allocate environmental resources. Environmental problems are essentially economic problems and the cost of environmental damage needs to be quantified and given value. Market incentives such as 'green taxes' (taxes on pollution) and the principle that the polluter pays, are advocated by neo-liberals (Smith, 1992: 285). This approach is associated with World Bank environment policy (World Bank, 1995:10).

In general, the environmental approach is more linked with the structuralist approach. However, environmentalists generally believe that economic growth is not compatible with environmental preservation. In general, the environmental approach focuses on reducing consumption levels in Industrialised countries. The environmental approach is also critical of the expansion of trade and the ability of the capitalist system to deal with global environmental problems (Smith, 1992: 285).

While these approaches are very broadly defined, there are many other approaches often incorporating principles from some or all of the above. Gladwin and Pearson emphasise that developing country leaders and planners have often regarded the issue of the 'environment' with great suspicion. Environmental standards can be imposed as a covert form of protectionism against LDC exports. (Gladwin, 1987: 4;

Pearson, 1987: 116).

There are two concepts which are pertinent to any discussion about the environment, industrialisation and development. Firstly, problems associated with resource use, pollution, ozone depletion and global warming are predominantly the result of industrialisation and consumption rates in industrialised countries (Keating 1993:15). Secondly, problems associated with access to safe drinking water, decent sanitation, loss of biological diversity, desertification and deforestation are of greater relevance to developing countries (for example soil erosion threatens societies dependant upon agriculture and regarding biological diversity, most varieties of plants and animals are located within tropical zones).

In light of the first concept, if developing countries industrialise using the same technologies as currently used by the industrialised countries and at the same rates of consumption, problems associated with global warming, ozone depletion, resource exhaustion and pollution are likely to intensify both globally and within developing countries. There is also the possibility that firms in industrialised countries have relocated their pollution and toxic waste to developing countries (or will do so). Production might be relocated in order to avoid strict environmental laws (or strictly enforced environmental laws) or toxic waste might be disposed. An example of this was uncovered in 2005, when more than 1,000 tonnes of contaminated household refuse from the UK and Ireland, and disguised as waste paper, was intercepted in the Netherlands on its way to be recycled in China. Alternatively firms may exhaust resources (timber, water etc.) in industrialised countries and move to LDCs to acquire new resources.

Following from the second concept, developing countries face different environmental problems than industrialised countries and industrialised agriculture will impact differently upon developing countries than it has done on Industrialised countries due to very different environments.

7.1 Industrialisation and the environment

Industrial production effects the environment through natural resource depletion (water, air, energy, materials and the reduction of biodiversity) and through pollution

of the environment (both physically through production plant or through toxic emissions, whether during production or in product use or disposal). The most crucial aspect of environmental impact is its extent. (For example, the rate at which greenhouse gases are building up in the atmosphere). While there is debate about the extent of the environmental impact of industrialisation, Hurtado (1995: 26) articulates the main concern:

> *"Nobody really knows when the world's consumption of natural resources will reach a point of no return. The same goes for pollution. What we do know is that the danger signals are flashing."*

Three approaches are common in dealing with the adverse environmental effects of industrialisation:

1. Reducing the level of Production and Consumption
2. Use of cleaner production methods and more 'environmentally sound' products.
3. Through environmental planning and waste and pollution management techniques.

The problem of over-consumption is described by Welford: (Welford, 1995: 15)

> *"One of the major factors which has allowed consumerism to boom has been the massive advances in technology and technological ability.... The result has been that the 1.2 billion people in the advanced industrialised countries consume vastly more, on all key indicators than the 3.4 billion who are adequately fed and clothed and the billion or more who live in absolute poverty... Although we might argue that history can provide us with all sorts of evidence to suggest that consumerism is not particularly new, a characteristic which we must accept is that the sheer scale of consumption is of a different order to anything known in pre-industrial times or periods of modernity."*

Agenda 21 specifically deals with changing the patterns of production and consumption. It states: (UNCED, 1992: Ch 4.3)

“the major cause of the continued deterioration of the global environment is the unsustainable pattern of consumption and production, particularly in industrialized countries, which is a mater of grave concern, aggravating poverty and imbalances”

There are two different ways of changing the pattern of production: reducing consumption in order quantitatively reduce environmental impact, or improving production methods and products in order to qualitatively alter environmental impact. By far the most significant is the former as stated during a meeting of UNCED in Oslo: (UNCED (Oslo), 1994: Ch 1.1)

“Many of today's trends in consumption and production patterns continue to go in an unsustainable direction. Total energy consumption is growing, despite efficiency improvements in industry and end-use appliances. The generation of solid waste has yet to be de-coupled from economic growth, while the projected increase in transportation poses one of the most serious consumption challenges for industrialised countries. Several research institutes have even suggested that OECD countries will need to cut their per capita pollution and resource intensities by a factor of 10 or more over the next half century if they are to reduce the burden they place on the global environment to sustainable levels. “

On the other hand, the latter option of qualitatively reducing environmental impact is the least problematic politically and economically. This was put succinctly at the Oslo meeting: (UNCED (Oslo), 1994: Ch 1.2)

“A key issue is therefore the extent to which necessary improvements in environmental quality can be achieved through the substitution of more efficient and less polluting goods and services (patterns of consumption), rather than through reductions in the volumes of goods and services consumed (levels of consumption). Political reality in democratic societies is such that it will be much easier to change consumption patterns than consumption volumes, although both issues need to be addressed.”

At the conference, a working definition of Sustainable Consumption was devised : (UNCED (Oslo), 1994: Ch 1.2)

> *"the use of goods and services that respond to basic needs and bring a better quality of life, while minimising the use of natural resources, toxic materials and emissions of waste and pollutants over the life cycle, so as not to jeopardise the needs of future generations."*

The goal of sustainable production and consumption primarily represents a challenge to countries that have already industrialised and need to limit over-consumption and its consequences. Nevertheless, there are a number of important considerations regarding Developing countries.

One view, is that the only way to attain a decent environment is to become rich through economic growth. (Beckerman, 1992: 482). Beckerman also points out that historically, 'limits to growth' have proved to be underestimates and new resources (for example of coal, oil) are always found to satisfy any given demand. (Beckerman, 1992: 483).

However, this (neo-liberal) view is in stark contrast to the structuralist approach, in which the developing countries will never be able to follow the development path of the more developed because there *must* be material limits to growth and this can only lead to increased inequality between rich and poor nations, since the richer nations will be better placed to acquire these resources through economic, political and military means. (Smith, 1992: 291)

The United Nations Industrial Development Organisation (UNIDO) estimates that a five to tenfold increase in world industrial output is necessary in order for consumption of manufactured goods in developing countries to reach current levels in industrialised countries. (Smith, 1992: 289).

A key to resolving the issue of patterns and levels of consumption lies in bridging the gap between the external costs of environmental impact and the cost to producers and consumers. In this regard, Governments are the key actors in providing infrastructure, incentives and regulation in order to achieve sustainability from production to consumption to disposal. (UNCED, 1994 Ch 1.4)

There are several tools which can be used to produce goods which are more

environmentally sustainable in terms of production, usage and disposal:

- Cleaner Production
- Life Cycle Assessment (described in the next section)
- End-use approach to consumption and energy management
- Environmental Space

(UNCED, 1994 Ch 1.4)

With regard to industrialisation strategies for Developing Countries, the following points are relevant from the prescriptive literature:

- New technologies offer opportunities for improving the environmental risk associated with industrialisation (Smith, 1992: 292; World Resources Institute1, 1987: 257; Zhenhua: 1995: 12)
- An effort should be made by Developed Countries to transfer cleaner technologies to developing countries (World Bank, 1995: 28; Smith, 1992: 291; Cavalcanti: 1995: 5)
- The emphasis should be on preventing environmental degradation (Cleaner Production) rather than on remedial action (Waste Management) (World Resources Institute1, 1987: 256)
- Cleaner Production, Life Cycle analysis and End Use Energy Management techniques can reap considerable economic savings (Larderel, 1995: 19; UNCED 1994: Ch 1.3,)
- TNCs, should adopt a similar environmental policy regarding their host country and their home country (World Resources Institute, 1987: 258)
- Changes can be made to consumption and production patterns in ways that sustain standards of living and enhance competitiveness and economic performance. (UNCED 1994: Ch 1.3)

These points do not contradict the need to determine the appropriate and sustainable levels of production and consumption world wide, and the need to face the problem of over-consumption in industrialised countries and the issue of equality between richer and poorer nations.

Environmental planning can be used to limit the extent of environmental damage. This is particularly important for developing countries. The location of industry can be planned through land zoning in order to separate factories from residential areas or water supplies. Infrastructure is important in order to cope with industrial wastes (water and electricity supply; waste treatment) (World Bank, 1995: 179; World Resources Institute, 1987: 256). Lastly, environmental damage can be cleaned-up. This is often a very expensive solution and questions arise over who is responsible for particular environmental impacts and therefore, who will pay.

7.2 Product design and environmental impact

The idea of sustainable production and consumption has been explored in section 8.1. In this section, the role of designers in producing ecologically sustainable products is explored. The attempt to design of ecologically sustainable products is sometimes referred to as "eco-design".

There are several reasons why designers engage in "eco-design", or take into account environmental factors in the design of products:

- Due to government regulations. (for example, a ban on the use of CFC gasses)
- Adherence to product standards which often specify safety/toxicity or energy requirements. For example those of the International Standards Organisation (ISO), and the British Standards Institute (BSI).
- Due to consumer (and consumer group) pressure - preference for more 'environmentally friendly' products
- Production - Design for waste reduction often reduces production costs through savings in material or energy usage
- Efficiency - More efficient products may be less expensive for consumers to purchase/maintain or operate
- Shortage of material resources - leads designers to explore alternative materials or product designs
- Moral - the impetus may come from decisions of entrepreneurs and designers

themselves.

The most comprehensive and structured approach to eco-design is Life Cycle Assessment (LCA). It is defined by Welford (1995: 99) as:

> *An analysis covering every stage and every significant environmental impact of a product from the extraction and use of raw materials through to the eventual disposal of the components of the product and their decomposition back to the elements.*

Welford states that it is at the design stage where much can be done to improve a product's environmental performance. LCA might involve the examination of forestry or mining techniques, energy and water use in production, material and product transportation, packaging, air and water pollution, and the repair, re-use and recycling of materials. The technique is designed to expose the environmental damage caused by products up or down the supply chain (Welford, 1995: 99).

The principal means by which products can be designed for environmental sustainability using the LCA system:

- Through the use of less materials or less parts
- By designing products which use less energy in production or use
- Through design for re-use and recyclability - so that constituent materials can be easily be extracted (sometimes new combinations of materials make recycling difficult).
- Through design for reliability - through increasing the product use life span - so that products need to be replaced less frequently
- Through using components, parts or materials which themselves minimise environmental impact.

Welford points out that 80 to 90 per cent of the total life cycle costs associated with a product are determined by its design. LCA pushes this fact to the forefront of product design activity. The main drawback of LCA, is that its effectiveness is limited by the limits of the study. For example, a petro-chemical firm might conveniently easily exclude the disposal of toxic chemicals in one of its constituent products.

Nevertheless it is necessary to limit the scope of an LCA study. The LCA system forms the basis of the European Union Eco-Label scheme (Welford, 1995: 99, 102).

While, there is much that a designer can do to reduce environmental impact, much of his or her efforts will depend on the legislative and organisational context in which products are used. For example many products have been designed for recyclability, yet there is no physical mechanism or economic rational for consumers or producers to recycle these products.

References:

References for this paper are available in an online bibliographic database system, available at:

www.ruadesign.org/ourbiblio/index.php