PART I

WHAT IS D4S AND WHY DO IT
1.1 FROM ECODESIGN TO DESIGN FOR SUSTAINABILITY (D4S)

In the 1990s, concepts such as Ecodesign and green product design were introduced as strategies companies could employ to reduce the environmental impacts associated with their production processes. These strategies also served to bolster a company’s position and competitive edge in a market where more and more emphasis was being placed on environmental stewardship. In 1997, UNEP published “Ecodesign: A Promising Approach to Sustainable Production and Consumption” which was one of the first manuals of its kind and helped lay the foundation for widespread adoption of Ecodesign concepts. This publication introduced the fundamental concepts of Ecodesign to policy makers, programme officers, and project specialists. The manual has been instrumental in the development of many other documents and sector specific publications on the topic.

In the last ten years, the global threats of climate change have pushed environmental concerns to the forefront of political agendas around the world. In response to these concerns, many nations have taken up the urgent call to ‘act now’. These countries have established policies designed to mitigate the deleterious effects of climate change by reducing greenhouse gas emissions, shifting energy supply to include a larger portion of renewable energy resources, and increasing energy efficiency.

While much emphasis is currently placed on climate change, other environmental issues and concerns are looming on the horizon. These include the availability of potable fresh water, increased deforestation, reduced biodiversity and the destruction of ecosystems. Reversing these trends requires dramatic changes in consumption and production at the process, product, service, and system levels.

Profound changes have taken place in the world economy and industrial production practices over the past decade. The accelerating processes of globalisation and trade liberalisation, supported by advances in information technologies, have fundamentally changed the landscape of the private sector in all countries. These changes have resulted in economies around the world becoming increasingly interconnected with developing economies playing a more and more important role in economic growth (i.e. China, India, Mexico, Brazil and Russia). In the wake of globalisation, it is becoming increasingly evident that current economic growth and development patterns cannot be sustained without significant innovation in both the supply (production) and demand (consumption) sides of the market. Therefore, there is a growing demand for companies to research and implement more innovative processes and develop better products and services. Governments can support this by providing a conducive policy environment and creating civil society programmes that facilitate the dis-
semination of information to promote the selection of sustainable products among consumers.

To keep pace with the rapidly changing industrial setting, many environmental movements have expanded their scope to include social and economic concerns. This combination of environmental, social, and economic priorities is referred to as 'sustainability.' Like many other environmental concepts, Ecodesign has evolved to include both the social and profit elements of production and is now referred to as sustainable product design. The concept of ‘Design for Sustainability’ (D4S) requires that the design process and resulting product take into account not only environmental concerns but social and economic concerns as well. The D4S criteria are referred to as the three pillars of sustainability - people, profit and planet. D4S goes beyond how to make a ‘green’ product and embraces how to meet consumer needs in a more sustainable way. Companies incorporating D4S in their long-term product innovation strategies strive to alleviate the negative environmental, social, and economic impacts in the product’s supply chain and throughout its life-cycle.

This step-by-step approach to D4S provides companies and intermediate organisations in developed and developing economies with practical support for both incremental and radical product innovation. It should be noted that by no means has incremental redesign or greening of products lost its relevance in today’s marketplace. D4S essentially builds on these concepts and aims to drastically improve the efficiency and social qualities of production processes by developing new products, services, and systems. This publication provides examples and approaches on how to accomplish these goals.

The D4S: A Step-by-Step Approach was compiled by Delft University of Technology’s Design for Sustainability (DfS) Programme for UNEP’s Sustainable Consumption and Production Branch of the Division of Technology, Industry and Economics. Both organisations have been active in the area of promoting more sustainable product design since the introduction of these concepts in the 1990s. The publication is a result of a long-term cooperation with international experts from the Netherlands, Sweden, Italy, France, Germany, Japan, Australia, UNIDO, the Swedish EPA, InWEnt Germany, and UNEP and reflects the evolution of the concept.

UNEP supports a variety of D4S efforts — strengthening resource efficiency and sustainable consumption and production is a UNEP priority area. UNEP does this through strengthening the knowledge base underlying action by government, industry, and consumers, building governmental capacity to implement policies and tools, and strengthening partnerships with business and industry. These include initiatives such as reporting on economics and development implications of resource depletion, establishing supply chain partnerships with SMEs to enable them to meet more stringent environmental standards, or training key stakeholders on resource efficiency and sustainable consumption and production. In the D4S area, UNEP has developed materials to help business leaders, product designers, and policy makers rethink how to design and produce products to improve profits, competitiveness, and social benefits while reducing environmental impacts. In addition to the Ecodesign Manual (1997), other publications and tools include: Design for Sustainability: A Practical Approach for Developing Economies (2006) (developed in conjunction with Delft University of Technology, it introduces the D4S concept and methods for applying it in a business setting in developing economies). Relevant examples and case studies are included from demonstration projects carried out in Costa Rica and Morocco. It is available in English, French, Spanish, and Vietnamese. Other manuals cover life-cycle management: Life-Cycle Management: A Business Guide to Sustainability (2007). UNEP’s work with UNIDO on the National Cleaner Production Centres (NCPC) Programme also highlights D4S as a focal area. For example, in 2008-9, UNEP is working with the Vietnamese NCPC to implement an EC supported project to test the D4S methodology. Disseminating the D4S concept globally is a long-term strategic focal area.

UNEP has an increased focus on design issues in sustainability efforts as a result of years of work in cleaner production and eco-efficient systems. The horizons of pollution prevention have widened from a focus on cleaner production processes to the broader concept of sustainable product design, and have expanded to include transport logistics, end-of-life collection, and component reuse or materials recycling. These product systems innovations in existing endeavors couple well with new products, systems, and enterprises designed to create win-win solutions for businesses, local com-
munities, supply chains, the environment, and consumers. Each product or system that is designed with resource efficiency and a full life-cycle analysis in mind contributes to the promotion of a 10 Year Framework of Programmes on Sustainable Consumption and Production patterns that was mandated at the World Summit on Sustainable Development in 2002. (http://www.unep.fr/scp/design/d4s.htm)

Delft University of Technology’s D4S Programme has extensive experience in sustainable product, service, and system innovation worldwide. Industrial and research projects are carried out in the areas of products, renewable energy, innovative mobility, renewable materials, sustainable Product-Service Systems, telemedicine, leisure products, and regional innovation. Projects have been executed in the Netherlands, Europe, Africa, Asia, and Latin America. Several of the corporate projects are used as examples and case studies in the publication.

1.2 TO WHOM IS THIS PUBLICATION ADDRESSED?

This publication is written for professionals involved in product innovation and sustainability, including innovators, product developers, company executive managers, environmental managers, intermediaries such as consultants, centres of excellence, and researchers. It is also relevant for professionals from business associations, NGOs, and governments that work with industry in joint projects. The type of D4S related methodologies proposed in this publication can be used in a collaborative process with several partners, either within a company, or within a project where intermediates and companies are involved. Certain chapters of this publication were written to be used by an in-company or external project team that can initiate D4S projects (i.e. the quick-start, and the redesign and benchmarking chapters). Other chapters outline concepts or initiatives that require a broader partnership of companies and societal actors, or a longer timeline for the execution of the project (i.e. the product innovation, product-service systems and system innovation chapters).

This publication is addressed to professionals in both developed and developing countries. It presents the concept, its rationale and context, and approaches to apply D4S. A separate publication on D4S in developing economies (D4S-DE) was published by UNEP in 2006. Given their unique and more immediate needs, particularly in the area of awareness and capacity building, the D4S-DE publication focused on needs assessment, redesign, and benchmarking of products and outlined a practical approach that is feasible for the context.

However, this does not exclude the importance of ‘leapfrogging’ towards new and more sustainable products, services, and systems which are presented in this step-by-step approach. As redesign and benchmarking can be highly valuable approaches in developed economies as well, text on product redesign and innovation is provided in Chapters 4 and 5, respectively. Information on benchmarking is detailed in Module A, and the worksheets on redesign and benchmarking on the web, are all similar to what has been presented in the D4S-DE publication.

1.3 HOW TO READ THIS PUBLICATION

This publication is comprised of four parts (Parts I-IV) - two are contained in this document (Parts I-II). Parts III and IV are a series of modules that are located on the webpage www.d4s-sbs.org <http://d4s-sbs.org>. Readers can navigate this publication in different ways depending on their interests and focuses. Reading suggestions are provided below.

In Part I, **What is D4S and why do it?** (Chapters 1 – 2), introduces the concepts and motivations for D4S initiatives. Chapter 2 provides an overview of the relationship between sustainability and product innovation and how to meet consumer needs while improving the environmental, social, and economical aspects of products. Chapter 2 also outlines the basic concept of product innovation and the difference between incremental and radical innovation. The three approaches featured in this publication — redesign, new product development and Product-Service Systems (PSS) — and their common basic steps (policy formulation — idea generation — strict development — realisation) are introduced. For each of the methods, these four steps are subdivided differently (see Figure 1-1), based on specific goals and requirements. As a final part of this chapter, the reasons for a
company to work on sustainable solutions are discussed.

Part II, How to do D4S (Chapters 3 – 7), is the publication’s core. This portion of the document outlines the practical design approaches to execute a D4S project in a company or network: Redesign, new product development and PSS development. Additional methods and tools are provided in modules on the web.

Chapter 3 is the Quick Start approach for D4S. This chapter aims to orientate readers on the D4S process and provides guidance on selecting from the various types of D4S approaches.

Chapter 4 describes the key incremental innovation strategy: D4S Redesign. This strategy is aimed at sustainability-driven, incremental improvement of an existing product. A closely connected approach, D4S Benchmarking, is presented in Module A on the web. This benchmarking approach advocates learning from competitors’ efforts and experiences to improve a company’s own products, and is especially suitable for companies that develop products by imitating existing prod-

![Diagram](image-url)
ucts. A comprehensive set of worksheets on redesign and benchmarking is included on the web.

Chapter 5 emphasises the importance of out-of-the-box or radical sustainable product innovation. It describes how to efficiently and effectively manage radical innovation and reduce risk.

Chapter 6 highlights new product development and shows similarities and dissimilarities with redesign. This chapter also provides examples of several innovative new product technologies, three of which are detailed in the innovation topic annexes on the web: application of new eco-materials (Module H), integration of new energy systems in products (Module I), and application of ICT technologies (Module J). Innovative new products are often part of system innovations on both the technical and socio-cultural level.

Chapter 7 details Product-Service Systems (PSS). This design approach was developed to accommodate the fact that services and products are becoming increasingly intertwined, and if properly designed and managed, can fulfill customer’s needs more efficiently and sustainably than purely product-based solutions. A step-by-step approach for a PSS pilot project is provided, and this methodology is further detailed in Module C on the web. Module B on the web also provides information and examples on design-oriented scenario building, which is closely connected to PSS.

The conclusion of this section provides suggestions for further reading.

Part III of the publication consists of Case Studies on the web. These five case studies that depict the concepts outlined in the previous chapters (drivers, Redesign, radical innovation, new product development and PSS). Each case begins by listing the company and stakeholders implementing the D4S initiative, the issue, the goals and process of the case, and finally the project results.

Part IV of this publication consists of the supporting materials on the web. These resources are grouped into the following categories: Design tools, Management tools, Design related innovation topics, and three sets of worksheets. The design tools are to be applied in combination with the methodologies described in Part II of this publication. The contents of Modules A, B, and C have already been presented. Module D provides an overview of creative techniques a D4S team can apply in developing novel solutions to product innovation challenges. Module E includes rules of thumb for implementing D4S projects. Management tools (Module F) and communication tools (Module G) are presented to assist professionals initiating D4S projects, as well as those responsible for internal and external communication.

Modules on innovation topics - eco-materials (Module H), energy (Module I), and ICT (Module J) - have already been presented in connection with Chapter 6 on new product development. Finally, three sets of worksheets on Redesign, PSS, and benchmarking are provided to better assist individuals targeting these efforts. The web also holds a printer-friendly version of the entire publication. The website with the same digital information and additional materials can be found at: http://www.d4s-sbs.org

An overview of the publication which highlights the relationship between the various Chapters and Modules is provided in Figure 1-2.

The following selections are recommended for fast track reading:

**Fast Track Reading Suggestions:**

I do not have an idea yet: Read Chapter 2: What is D4S and Why Do It? and Chapter 3: A ‘Quick Start’ approach to D4S. Browse through rest of the publication. After that, decide what you want to do and see below.


PUBLICATION OVERVIEW
D4S A STEP-BY-STEP APPROACH

In the book

1 > INTRODUCTION
2 > WHAT IS D4S AND WHY DO IT
3 > 'QUICK START' APPROACH

4> IN-THE-BOX: D4S REDESIGN
5> OUT-OF-THE-BOX: RADICAL D4S
6> NEW PRODUCT DEVELOPMENT
7> PRODUCT-SERVICE SYSTEMS

On WWW.D4S-SBS.ORG <HTTP://WWW.D4S-SBS.ORG>

8> D4S CASE STUDIES

DESIGN TOOLS
A. Benchmarking
B. Design-Oriented Scenarios
C. Product-Service System tools
D. Creativity Techniques
E. D4S Rules of Thumb

MANAGEMENT TOOLS
F. D4S Management
G. D4S Communication

WORKSHEETS
Redesign
Benchmarking
Product-Services

INNOVATION TOPICS
H. Eco-material
I. Energy
J. ICT

FIGURE 1-2 — PUBLICATION OVERVIEW
2.1 Products and Sustainability

It is increasingly apparent that current patterns of consumption and production are unsustainable, as evidenced in the ever increasing rate of adverse environmental and social impacts. The accelerating processes of globalisation and trade liberalisation, supported by advances in information technologies, have fundamentally changed the landscape of the private sector in both developed and developing economies, providing new opportunities to improve sustainability. Large and small companies have made impressive efforts to address sustainability issues with a bottom line focus. Companies are improving the efficiency of current production and the design of new products and services through supply chain management, corporate reporting, benchmarking, and adopting related international standards.

These profit-driven strategies go by many names, such as sustainable product design and Design for Sustainability (D4S). D4S, which includes the more limited concept of Ecodesign (Chapter 1 describes the evolution of Ecodesign to D4S), is one globally recognised way that companies can improve efficiencies, product quality, and market opportunities while simultaneously improving environmental performance, social impacts, and profit margins. Many developed economies are highly aware of the business opportunities related to efficiency increases and more stringent environmental and social standards. D4S efforts have already been linked to wider concepts such as product-service mixes, systems innovation and other life-cycle-based efforts. In developing economies, more immediate technical support is needed to introduce the D4S concept.

Many organisations have developed tools to help companies, designers, and consultants rethink how to design and produce products in a way that improves profits and competitiveness while reducing adverse environmental impacts. Over time, this process, known as Ecodesign, has evolved to encompass broader issues such as the social component of sustainability and the need to develop less resource-intensive ways to meet consumer needs. D4S goes beyond how to make a ‘green’ product and addresses how to best meet consumer needs on a social, economic, and environmental level. This does not only include the individual product, but also the system of products and related services which are jointly capable of fulfilling consumer needs more efficiently and with a higher value for both companies and consumers.

The 3 key elements of sustainability – social, environmental, and economic – are also referred to as people, planet, and profit, and are the fundamental components of product innovation (see Figure 2-1).

To be sustainable, product innovation must work within a number of frameworks linked to people, planet, and profit, including social expectations, equitable distribution of value along the global value chain, and the carrying capacity of the supporting ecosystems. Examples of sustainability challenges include:
PEOPLE: CREATE OPPORTUNITIES TO MEET SOCIAL AND EQUITY REQUIREMENTS

- Reduce urban and minority unemployment
- Improve working conditions, safety, and well-being
- Acceptance and integration of minorities
- Reduce income inequity
- Enhance number of skilled workers
- Abolish child labour
- Reduce illiteracy
- Provide basic health services
- Provide clean drinking water
- Reduce population growth
- Improve status of women
- Adopt international employment standards
- Increase social opportunities and community interaction
- Abolish large scale dislocation of people

PLANET: FIT WITHIN THE CARRYING CAPACITY OF SUPPORTING ECOSYSTEMS

- Reduce fossil fuel energy use
- Use of renewable energy
- Increase energy efficiency
- Reduce use of toxics
- Clean contaminated sites
- Improve level of waste prevention, recycling, and reuse
- Reduce and treat industrial emissions
- Reduce quantity of waste water and promote treatment

> Stop overexploitation of renewable resources and water
> Stop deforestation, soil loss, erosion, and ecosystem destruction
> Reduce dung and wood burning

PROFIT: CREATE EQUITABLE VALUE FOR CUSTOMERS AND STAKEHOLDERS ALONG THE GLOBAL VALUE CHAIN

> Value for company and stakeholders
> Value for customers
> Fair business model
> Fair share of and linkage to global value chains
> Linkage of small and medium sized enterprises in developing countries to large transnational companies
> Fair price for commodities and raw materials
> Ownership and credit opportunities for entrepreneurs

The company capacity to undertake D4S initiatives is highly variable from one organisation to the next. If organisations with lower D4S capacity levels were expected to integrate every element outlined above, many product innovation ideas would not be implemented. Furthermore, the above mentioned elements may not be relevant to all companies and countries. To facilitate the D4S process and maximise project impact, companies should review their sectoral needs to identify the design aspects that would yield maximum positive impacts and the successful achievement of goals and targeted elements of D4S projects.

A carefully prepared D4S project can have a significant impact on a company’s future competitiveness, as well as immediate benefits. Sustainability requirements are increasingly being incorporated into corporate supply chain requirements, government procurement guidelines, and consumer decision making.

During the development of a new product, or the redesign of an existing one, the product development team is confronted with a variety of design criteria such as quality, ergonomics, safety, and aesthetics. When using the D4S approach, environmental, social, and profit criteria are integrated into the product development process along with elements that serve to minimise the adverse impacts of the product throughout its life-cycle.
2.2 Products and Environmental Aspects - Planet Implications

In the late 1980s and early 1990s, sustainability was largely an environmental issue. Initially efforts focused on improving end-of-pipe technologies, designed to treat waste and polluting streams. In the mid-1990s, the focus shifted towards production improvements via concepts such as clean technology, cleaner production, and eco-efficiency. The next shift was to product impacts, thereby taking into account the whole product life-cycle. Concepts like Ecodesign and Design for the Environment (DfE) were developed and put into practice to address the environmental concerns associated with production and consumption processes. D4S is the latest evolution of product design and takes into account the overarching goals of sustainability, which include social and economic concerns.

Environmental impacts can be divided into three main categories: ecological damage, human health damage and resource depletion (see Table 2-1). These impacts, including eutrophication, land use, ecotoxicity, human health damage, and the depletion of fossil fuels and fresh water, are relevant to large industries and SMEs in both developed and developing economies.

Another way to classify the different types of environmental impacts is by geographical scale - local, regional, fluvial, continental, or global. Typically, the higher the scale level, the more sources that contribute to the impact, the greater the need for international collaboration to solve issues, and the longer it takes for improvements to become visible – depending on the reversibility of the problem. A legal framework is in place for many industrialised countries to enforce regulations that deal with local problems like water pollution, soil pollution, and waste disposal, however, while developing economies may possess a similar legal framework, they may lack the enforcement capacity necessary to successfully address these issues. Global issues like climate change are best tackled through international cooperative global warming mitigation efforts. Irreversible depletion problems, even when occurring locally, such as loss of topsoil, are not easily solved, therefore preventive steps to avoid depletion are the most cost-effective. After preventative solutions, back-

<table>
<thead>
<tr>
<th>TYPE OF IMPACT</th>
<th>DESCRIPTION</th>
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<tbody>
<tr>
<td>1. Ecological Damage</td>
<td></td>
</tr>
<tr>
<td>Global warming or climate change</td>
<td>Addition of greenhouse gases to the atmosphere from burning of fossil fuels, agriculture, industrial practices. Effects: temperature change, increased incidence of storms, desertification, tropical disease, ocean current changes, sea level rise.</td>
</tr>
<tr>
<td>Ozone depletion</td>
<td>Stratospheric ozone depletion caused by emissions of CFCs. Effects: increased amount of UV radiation leading to increased cancer occurrence, reduced productivity of plants, marine algae and high altitude biota.</td>
</tr>
<tr>
<td>Acid rain</td>
<td>Acidification of precipitation by emission of sulphuric and other substances, mainly from fossil fuels. Effects: dissolves metals from the soil which become toxic to plants and aquatic organisms.</td>
</tr>
<tr>
<td>Water eutrophication</td>
<td>Addition of excess nutrients to water, leading to algae bloom and consequent reduction of available oxygen. Effects: killing of fish and other aquatic organisms.</td>
</tr>
<tr>
<td>Habitat alteration (land use)</td>
<td>Physical modification or destruction of natural habitats for agriculture, forestry, roads and urban growth. Effects: Primary cause of loss of biodiversity.</td>
</tr>
<tr>
<td>Ecotoxicity</td>
<td>Exposure of plants, animals and other biota to toxic substances. Wide range of effects.</td>
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</tbody>
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<table>
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<tr>
<th>2. Human Health Damage</th>
<th></th>
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<tbody>
<tr>
<td>Smog and air pollution</td>
<td>Emission of nitrogen oxides and VOCs generates ground level ozone, other air pollutants include dust particles and sulphur dioxide. Effects in human: increased incidence of asthma and other health disorders.</td>
</tr>
<tr>
<td>Health damaging substances</td>
<td>Non-cancer causing substances include skin irritants, growth inhibitors, endocrine disruptors.</td>
</tr>
<tr>
<td>Carcinogens</td>
<td>Cancer causing substances, mutagens that cause genetic mutation (most of them are also carcinogenic), teratogens cause defects in developing embryos.</td>
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</tbody>
</table>

<table>
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<tr>
<th>3. Resource Depletion</th>
<th></th>
</tr>
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<tbody>
<tr>
<td>Fossil fuels</td>
<td>Current consumption rates of oil, gas, coal convert fuels into materials, energy and CO2 at a rate millions of times faster then nature can replenish the fuel reservoirs.</td>
</tr>
<tr>
<td>Fresh water</td>
<td>Consumption of fresh surface or groundwater converts them into forms that are typically nonrecoverable. Access to clean, potable water is a fast growing international problem.</td>
</tr>
<tr>
<td>Minerals</td>
<td>Metal ores are converted into metals and alloys that are eventually oxidized or dispersed as waste that is often not recycled.</td>
</tr>
<tr>
<td>Topsoil</td>
<td>In many places, agriculture and forestry erodes topsoil at a rate much faster then natural processes replenish it.</td>
</tr>
</tbody>
</table>

TABLE 2-1 - ECOCAL IMPACT CATEGORIES
stopping technologies like CO2 sequestration and toxic waste incineration will remain necessary to tackle problems on all scales.

### 2.3 Products and Social Aspects - People Implications

Social aspects of sustainability have begun to receive more attention from the media over the last 10 years as exemplified by negative articles on child labour, companies running 'sweatshops', workers' rights and indigenous peoples. Corporate strategies increasingly include corporate social responsibility in addition to economic and environmental priorities. These social concerns are relevant to all stakeholders, including investors, participants in a supply chain, and local communities.

Products and the production process impact people in a variety of ways. Understanding the vast spectrum of societal aspects relevant to sustainable production better equips companies to assess impacts and design and/or modify existing product designs to enhance the positive societal impacts and decrease the negative.

Table 2-2 outlines societal aspects of sustainable production and potential impacts. Societal impacts can include on-the-job injuries, consumer and employee health effects to chemical exposure, exploitation of labour, child labour, and resource conflict (diminishing water and food supplies).

### 2.4 Products and Financial Aspects - Profit Implications

In addition to environmental and social benefits, D4S can also help a company’s bottom line. Sustainability improvements made to products can lower production costs through increased resource efficiency, open up new markets and improve the quality of the product produced, increase customer loyalty and marketing opportunities, and link smaller companies to global value chains and multinational companies.

D4S improvements often involve the improvement of resource efficiency during production and an overall 

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**SUPPLY CHAIN**

| Human Rights | Protection of employees' basic rights, such as freedom of speech, right to fair wages, and absence of discrimination. |
| Child Labour | Elimination of the economic exploitation of children, which interferes with their education, health, and physical, mental, spiritual, moral, or social development. |
| Workplace Health & Safety | A high-quality work environment that protects the health and safety of employees and promotes workplace diversity, vocational education, and quality work-life balance. |
| Governance & Management | Systems and processes which govern accountability, transparency, responsibilities of various stakeholders. Can also include documentation, reporting, strategy, and risk management. |
| Transparency | The degree to which a company involves its business partners in carrying out its sustainability strategy and publishes information on its practices and behaviour in an accessible format. |
| Corruption & Bribery | A stable, ethical, and transparent economic environment that facilitates the mobility of investment, finance, and technology. |

**LOCAL AND SOCIODEMIGIC IMPACTS**

| Economic Growth | Sharing the benefits of an investment and the tools for economic growth with local businesses and community members. |
| Community Development | Facilitation of the development of health, education, water and sanitation resources in a community, as well as supporting local efforts to eradicate corruption and human rights violations. |
| Stakeholder Engagement | Consulting with non-business stakeholders on key sustainability issues, possibly in the form of open dialogue with societal partners (NGOs, government, community groups). |
| Distributed Economies (DE) | Distribution of a selected share of production to regions which support small scale, flexible units that are connected with each other and prioritise quality production. |

**SOCIODEMIC IMPACTS**

| Saline Encroachment | Overtaxing groundwater resources in coastal areas can cause saltwater intrusion whereby the over withdrawal of potable groundwater resources pulls saline water into freshwater areas which can contaminate drinking water supplies. |
| Land Subsidence | Over withdrawals from certain aquifer lithologies reduces the pore water pressure, increasing the effective stress which leads to the irreversible subsidence or sinking of the land surface. Societal impacts include reduced groundwater resource capacity and cracking building foundations. |

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**TABLE 2-2 SOCIAL IMPACT ASPECTS**
reduction in material and energy used. More resource efficient production can contribute to significant material savings for companies through reduced material use, reduced energy consumption, and increased recycling. Additionally, reduced material and energy requirements can insulate profit margins from volatile energy and commodity markets.

The greening of products can open up new markets that have previously been out of reach due to regulatory requirements or consumer preferences, and allay consumer fears over contaminated products. Sales can also be increased through expanding marketing opportunities and strengthened customer loyalty. A company’s market position can be reinforced and enhanced via links to global value chains and multinational companies brought about by D4S initiatives.

2.5 LIFE-CYCLE AND IMPROVEMENT FACTOR THINKING

2.5.1 LIFE-CYCLE

The D4S approach is based on taking the entire life-cycle of a product into consideration when evaluating sustainability impacts (See Figure 2-2). The product life-cycle starts with the extraction, processing and supply of the raw materials and energy needed for the product. It then covers the production of the product, its distribution, use (and possibly reuse and recycling), and its ultimate disposal. A variety of environmental and social impacts occur in different phases of the product life-cycle and should be accounted for in an integrated way. Key environmental factors are the consumption of input materials (water, non-renewable resources, and energy in each of the life-cycle stages) and production of output materials (solid and chemical waste, wastewater, heat, and emissions) and factors like noise, vibration, radiation, and electromagnetic fields. Key social factors are labour policies, production processes that use toxic chemicals to generate products that can adversely affect workers and consumers, and unsustainable consumption of natural materials that ultimately adversely impacts ecosystems and biodiversity in local communities. An example of a product life-cycle evaluation is provided in Box 2-1.

Though they are the subject of much environmental focus, raw material provision and factory production are only two stages of the product life-cycle. In many cases, the distribution, use and disposal phases have higher environmental than the production itself. The environmental and challenge for D4S is to design products that minimise environmental and impacts during the entire product life-cycle, not just during production.

Various parts of the value chain connected to a product’s material life-cycle should also be considered to fully address social concerns. Social issues in each phase must also be addressed. Specifically, social concerns can arise around child labour, employee wages, and equal opportunities in the production phase with relation to the employees.

As a product reaches a consumer, compliance, health, and safety issues also highlight the social impacts.

In many cases, the added value generated during different steps of the life-cycle varies considerably; it is often relatively low in the extraction and production steps and higher in the sales and service steps.

**BOX 2-1: THE LIFE-CYCLE OF A SHIRT**

Shirts are often a combination of natural and synthetic fibers. To produce natural fibers (e.g., cotton), energy, fertilisers, water, and pesticides are needed. For synthetic fibers, chemicals, water, and energy for extensive manufacturing are required. These fibers are combined into cloth during a process.
which uses water, energy, and chemicals to give cloth its colour and other characteristics. From the cloth, shirts are produced and then packaged and distributed to retail shops. After the consumer has purchased the shirt, he or she will discard the packaging and will use the shirt. During the use phase, the shirt, on average, will be worn 100 times, washed, dried and maybe even ironed. Each of these steps has environmental impacts resulting from detergent, water, and energy use. Finally, perhaps when some parts of the shirt have worn out, it will be discarded. It is not possible to compost it because of the synthetic parts, and it may not be easy to recycle because of the mixed materials. During its life time, components of the shirt may have traveled thousands of kilometers, since the production of the cloth production could have occurred in Asia, the manufacturing of the shirt in North Africa, and the retail in Europe. There are also social implications within this lifecycle. Social aspects could include the working conditions on cotton plantations, as well as in the production facilities where cotton and other synthetic fibers are developed into usable materials, and finally the factories where the garments are manufactured. The labour policies used throughout this process can have adverse social impacts (one such example is sweatshops employing child labour). When evaluating and seeking to improve social impacts throughout the life-cycle, efforts should be made to promote a better distribution of benefits throughout the value chain.

2.5.2 IMPROVEMENT FACTORS

Sustainability also requires taking the needs of future generations into account, which means future environmental and social concerns need to be addressed. Global environmental pressures are directly related to the size of the population which helps define consumption levels, and the materials and energy required to produce each ‘unit’ of consumption. It has been estimated that environmental pressures should be reduced by about half. Taking into account the current growth rates of developing economies, the efficiency of products and processes needs to be improved by a factor of 4. Future generations could be living in a world with a population of 9 billion, and much higher consumption levels, which would require materials and energy improvements by a factor of 10 to 20.

This type of ‘factor thinking’ or ‘factor X thinking’ shows the magnitude of the task at hand, and the critical need to improve production processes, products, and systems. Short-term incremental redesign of existing products, also called ‘inside-the-box’ innovation, can typically lead to improvements of a factor of 2 to 4. To achieve long-term factors of 10 to 20, radical product innovation, or outside-the-box-innovation, is necessary. This includes developing completely new products, improving products as well as the services connected to them, and developing entirely new functional systems of products and services. Figure 2-3 illustrates the different degrees of environmental benefit and innovation required.

In the next section, the different types of innovation are explained in more detail.

![Figure 2-3: Degrees of environmental benefit and type of innovation required](image)

2.6 PRODUCT INNOVATION

Since D4S is based on a combination of product innovation and sustainability, understanding the underlying concepts of (product) innovation can be helpful in implementing D4S projects. This section discusses different approaches to innovation.
2.6.1 INNOVATION

Product innovation is essential for industry’s competitive position as well as for a country’s economic growth. Companies operate in a rapidly changing world in which customer needs and wants are not fixed and industry faces increasing competition due to open markets and globalisation. Companies that effectively integrate innovation into their product development process can gain a significant competitive advantage.

Innovation is a broad concept that is used in many different contexts. As a result, there are many definitions of innovation. One useful definition is: “the commercial or industrial application of something new— a new product, process or method of production; a new market or source of supply; a new form of commercial, business, or financial organisation”.

Most definitions of innovation emphasise ‘newness’ and ‘successfulness’. There are distinctions made between product versus process innovations and sometimes amongst market, business, and management innovation. For example:

> **Product innovation** is the introduction of new products that have characteristics and/or use applications that differ from existing products on the market.

> **Process innovation** is the introduction of a new method of production that has not previously been used, or a new way of handling a commodity commercially, to make production more efficient or to produce new or improved products.

> **Market innovation** involves entering new markets, expanding existing markets, and/or developing new ways of serving customers.

> **Business and management innovation** involves developing new reward systems, organisational structures, and ways of handling responsibilities and human resources etc. that positively affects product sales.

D4S efforts usually focus on product and market innovation, while cleaner production is linked to process innovations and environmental management systems like ISO 14001 are associated with management innovations.

2.6.2 INNOVATION LEVELS

Innovation can be categorised into three levels: incremental, radical, and fundamental (see Figure 2-4). Each category is progressively more significant and far-reaching.

1> **Incremental innovation**. Entails step-by-step improvements of existing products and tends to strengthen market positions of established companies in the industry. This includes benchmarking approaches in which products of competitors are copied and/or improved.

2> **Radical innovation**. Drastically changes existing products or processes. The risks and investments required for radical innovation are usually considerably greater than those needed for incremental innovation but offer more opportunity for new entrants to the market.

3> **Fundamental innovation**. Depends on new scientific knowledge and opens up new industries, causing a paradigm shift. In the early stage of fundamental innovation, the contributions of science and technology are important.

There is a wide range of innovation possibilities between the two extremes of incremental and fundamental innovation. Fundamental innovation often takes place only in large multinational companies, company clusters or national and international research programmes because of the large human and capital investment needed.

The majority of companies engage in incremental or radical innovation efforts. Successful incremental or radical innovation requires different kinds of thinking, working, and risk taking. For more insight into both types of innovation, a more detailed discussion of each is included below.
INSIDE-THE-BOX: INCREMENTAL INNOVATION

As the name suggests, this type of innovation makes small changes over a period of time. Incremental innovation is sometimes referred to as continuous improvement, and the business attitude associated with it is ‘inside-the-box’ thinking. A simple product may be improved (in terms of better performance or lower costs) through the use of higher performance components or materials. A complex product that consists of integrated technical subsystems can be improved by partial changes to one level of a sub-system. Incremental innovations do not involve major investments or risk. User experience and feedback is important and may dominate as a source for innovation ideas. As an example, customer preferences can be identified and added as features to the existing product.

Incremental innovation and design improvements are known as the ‘bread and butter’ of product innovation for many firms. Many firms do not even attempt to explore radical innovation for a variety of reasons having to do with their size and resources, the nature of the industry, the level of research and development required, or the amount of risk involved. Even firms that successfully introduce radical innovation may not do so very often. Incremental innovation projects, due to the low-level of involved risk usually follow a structured and predictable process.

OUT-OF-THE-BOX: RADICAL INNOVATION

Radical innovation involves the development of new key design elements such as change in a product component combined with a new architecture for linking components. The result is a distinctively new product, product-service, or product system that is markedly different from the company’s existing product line. A high level of uncertainty is associated with radical innovation projects, especially at early stages. Technical, market, organisational, and resource issues all need to be addressed.

Two primary types of radical innovation:
- New-to-the-Market: Novel substitutes, based upon new products to society;
- Breakthrough: Significantly changes the existing industry or creates a new business.

In the well-known Ansoff matrix (Figure 2-5) these two types are included in the ‘out-of-the-box’ approach. It means that the idea is based upon (1) a new technology or product; or (2) it is new to the market; or (3) both. Product innovations based on a new technology or product and new customers have the highest risks not to be adopted in the market.

In many cases, established companies are not able to create new-to-the-market or breakthrough solutions, because they would potentially jeopardise the existing business model and/or industrial infrastructure itself. Therefore, radical product innovation usually requires an ‘outside-the-box’ approach. Outside-the-box innovation aims to create an approach that goes beyond existing business models and links with other companies to create a new venture. The risks involved with outside-the-box innovation are significantly higher than those associated with inside-the-box innovation. The outside-the-box innovation process is more volatile and the outcomes more uncertain; the time horizon also tends to be much longer.

THE NEED FOR RADICAL INNOVATION

To reach sustainability from a ‘planet’ point of view, large improvement factors are necessary, which can only be
reached with radical innovation.

Furthermore, radical innovation is increasingly becoming an economic necessity for companies. For years, incremental innovation and inside-the-box thinking were considered the most successful way to innovate, and that still might be the case for many companies. Recently however, many consumer goods companies are faced with poor returns on their investments because markets in developed countries have matured and sales of incrementally improved products are decreasing. In sharp contrast, sales of breakthrough innovations are shown to have dramatically increased. Another signal is the change in supply scenarios: resources and raw materials are becoming scarce and more expensive.

Clearly, the need for radical innovation is growing, not only from an environmental but also from an economical point of view.

2.7 A SYSTEMATIC APPROACH

A systematic approach for product innovation has been developed by Roozenburg and Eekels and is shown in Figure 2-6. It consists of four basic steps: formulating goals and defining strategies for product development based on market perceptions; generating and selecting ideas for the new or improved product; developing these ideas into the blueprint of the new product; and transforming the plans into reality including production, distribution, sales, use and end-of-life assessment. Of course an actual product innovation process will often be more chaotic, iterative, and less linear than described here, but the fundamental steps can usually be recognised and are necessary for successful innovation.

Part II of this publication presents guidelines and stepwise approaches for both incremental and more radical product innovation. Three common approaches to product design include: redesign, new product development and product-service systems and will be discussed in the context of sustainable product innovation. Each category has its own specific requirements and issues, but the basic four steps shown in Figure 2-6 are common to all.

Figure 2-7 depicts the three main design approaches: Redesign, new product development and Product-Service Systems. The four basic steps are clearly shown for each. Chapters 4, 6 and 7 are devoted to explaining these design approaches in more detail and distinguishing the similarities and differences.

2.8 WHY DO D4S – DRIVERS FOR INDUSTRY

2.8.1 INTERNAL AND EXTERNAL DRIVERS FOR D4S

As described in the previous sections, there are compelling reasons for society to work on more sustainable solutions to the environmental, social, and economic problems the world is facing today. Furthermore, sustainability, corporate social responsibility, and related trends are part of the business agenda for an increasing number of companies worldwide. This is not only the case for most transnational companies, but also for a growing number of medium-sized and smaller companies. Understanding how to integrate these concepts into business planning can be an important part of a successful business strategy. Pressure to integrate sustainability requirements into corporate practices will come from government, business partners, non-governmental organisations, and citizen groups.

Motivation to implement D4S can come from within a business itself (internal drivers) or from outside a company (external drivers). Although there are overlaps amongst the people, planet, and profit aspects of sustainability, a driver is usually connected to one of them. Understanding the most influential drivers for a company or product can provide valuable information on the most effective types of D4S projects and activities to initiate. Table 2-3 presents common drivers for each of the three key elements of sustainability: people, planet, and profit.

For industry in developed economies, a mix of internal and external drivers for D4S generally exists, since
legislation, policy, and public opinion on sustainability are well developed. For industry in developing economies, internal drivers are more decisive for the initiation of D4S projects than external drivers, because external drivers currently are less developed.

2.8.2 Business Opportunities and D4S

Another way to evaluate reasons for industry to engage in D4S is to analyse the various business opportunities arising from these initiatives. The following three categories outline resulting business opportunities.
INTERNAL DRIVERS FOR D4S

'PEOPLE' ASPECT

_Social equity_ Can reduce risks on social and labour problems. As a result it can help avoid liability and reputation problems. 
_Strong social policy_ Can increase employee motivation. Employees can gain energy and experience from social projects and programmes launched by a company.
_Governance and management systems on social aspects_ Can make company achievements more visible to shareholders and stakeholders.

'PLANET' ASPECT

_Green marketing_ The design and production of products with environmentally value-added elements can boost brand value and reputation.
_Environmental awareness_ Managers often are aware of the importance of environmental issues and want to act accordingly.

'PROFIT' ASPECT

_Reach new consumers_ Surveys demonstrate that consumers are increasingly ready to purchase on ethical grounds.
_Product quality improvement_ Reliability and functionality often go together with a more sustainable product.
_Saving costs_ Cost reductions can be made on material use, energy, waste treatment charges, transport and the distribution system.
_Boost brand value and reputation_
_Product innovation_ New possibilities from product innovation can find solutions to meet customer needs and wants.
_Brand differentiation_
_New opportunities for value creation

EXTERNAL DRIVERS FOR D4S

'PEOPLE' ASPECT

_Public opinion_ Consumers are increasingly interested in the world that lies behind the product they buy, which is leading companies to take environmental and social issues into account.
_NGO pressure_ For years industries have been under fire from NGOs for controversial practices and the related impacts on the environment. For example: Irresponsible company practices may lead to boycott campaigns which can cause significant damage to a company reputation.

'PLANET' ASPECT

_Legislative requirements_ on environment will increase in many developing economies and can force a company into a more proactive stance.
_Disclosure requirements_ of environmental information towards suppliers and customers can start an improvement process in the company.
_Ecolabelling schemes_ can be an additional element for a companies' marketing strategy.
_Consumer organisation requirements_ such as safety, low toxicity and recyclability of products can be an incentive for D4S. Products failing to get ‘a good score’ on these aspects may no longer qualify as a ‘good choice’ in consumer tests.
_Pressure from dedicated environmental groups_ have forced industry to eliminate substances like CFCs from their products. These often highly professional organisations will continue to expose environmental harmful products.
_Direct community ‘neighbour’ pressure_ is often directed towards environmental and safety risks of the company and can have a large impact on production and products.

'PROFIT' ASPECT

_Norms and standards_ on sustainability aspects of products will continue to become stricter and may force companies to improve products.
_Subsidy schemes_ are available in some countries to improve sustainability aspects of products and production. At the same time, subsidies on energy and raw materials are ending, forcing companies improve materials and energy efficiency.
_Suppliers competition_ is evolving to enter or remain in the supply chain, pushing companies to become more sustainable.
_Customer demand_ for healthier, safer and more environmental and socially responsible products is increasing in specific product categories.
_Market competition_ is growing as competition increases at local and global levels. Industry may look to improve innovative performance, which might include reviewing the sustainability aspects of their products.

> **Cost savings and risk reduction opportunities**

Some of the business opportunities can be realised in a short timeframe. For instance, if a company manages to cut back on the amount of raw material, energy, or water used, this translates to direct savings in production costs. Similar benefits can be achieved by lowering the costs for cleaning equipment, waste management, tax savings, and reduction of future liability risks.

> **Enhancing image and market opportunities**

D4S can be a decisive factor in the creation of new markets or in competition in existing markets. Also,
improvements in the quality of products improved by D4S can enhance the market position of the company. Furthermore, market research indicates there are a growing number of green investment funds offered by financial institutions: access to investment funding can be a beneficial effect of D4S implementation.

> Legislative, social, and business requirements
Societal concerns also signal business opportunities. In order to maintain their competitive edge in the market, companies will be required to address consumer concerns and take advantage of up-coming trends. In addition to the well known legislative requirements, buyer and supplier demand, and pressure from societal groups is becoming a more important factor.

An overview of the most common drivers from the perspective of business opportunities and challenges follows.

**Cost saving and risk reduction opportunities**

> Saving raw materials
> Saving energy
> Saving water
> Savings in emission and waste treatment
> Savings in environmental taxes and fees
> Savings in product transportation (distribution)
> Reduction of insurance costs
> Reduction of accident costs
> Reduction of future liability risks
> Postpone disposal costs by offering Product-Service Systems (PSS)

**Image enhancing and business opportunities**

> Competition (retain markets, create new markets)
> Quality improvements that can enhance market position
> Customer demands (eco-labels)
> Branding and image creation
> CSR – Corporate Social Responsibility
> Improving worker health and safety issues
> Motivating employees and creating enthusiasm

> Enhancing innovation capacity
> Low profit margins call for new business ideas
> Improved access to green investment funding
> Building enduring producer-consumer relations by offering PSS

**Legislative, social and business requirements**

> Bans of toxic substances
> Take-back legislation – Extended Producer Responsibility
> Recycling requirements or recycled content requirements
> Emission limit standards
> Legislative information requirements
> Public procurement
> Buyer or supplier demands
> Pressure from environmental or other citizen groups
> Free customer of responsibilities for managing waste and hazardous substances by offering PSS

Case: A company committed to sustainability in all its aspects is Natura in Brasil. In the Case Study section on the web, the case of Natura is described with clear reference to the various drivers for D4S that influenced the strategic decisions of the company.