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Article

Design for Sustainability: Current Trends in Sustainable Product Design and Development

Garrette Clark [1,*], Justin Kosoris [1], Long Nguyen Hong [2] and Marcel Crul [3]

[1] United Nations Environment Programme, Department of Technology, Industry and Economics, 15 rue Milan, 75441 Cedex 09, Paris, France; E-Mail: kosoris@gmail.com

[2] Vietnam Cleaner Production Centre, 4th floor, C10 Building, Hanoi University of Technology, DHBKHN, Dai Co Viet Road, Hanoi, Vietnam; E-Mail: nghglong@gmail.com

[3] Delft University of Technology, Industrieel Ontwerpen, Room 1A-40, Landbergstraat 15, 2628CE Delft, The Netherlands; E-Mail: m.r.m.crul@tudelft.nl

* Author to whom correspondence should be addressed; E-Mail: garrette.clark@unep.org; Tel.: + 33-01-44-37-14-20; Fax: +33-01-44-37-14-74

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Abstract: The Design for Sustainability (D4S) concept outlines methodologies for making sustainable improvements (social, economic and environmental) to products by applying elements of life cycle thinking. D4S builds on the work of ecodesign to include economic and social concerns, and its methodology includes both incremental and radical innovation. The United Nations Environment Programme and the Delft University of Technology, the Netherlands, in concert with key partners, work to support, illustrate, and diffuse targeted D4S demonstration efforts, including the European Commission-funded Cleaner Production for Better Products project in Vietnam, that are needed to change unsustainable consumption and production patterns.

Keywords: ecodesign; Cleaner Production; Design for Sustainability; Product-Service Systems; developing countries; D4S; green products; sustainable innovation

1. Introduction

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. One ecodesign methodology, Design for Sustainability (D4S), has evolved from general

Cleaner Production methods to focus on products and to include social, economic, and environmental elements of production; the United Nations Environmental Programme, Division of Technology Industry and Economics (UNEP), is a key player in this field, partnering with various institutions like the Delft University of Technology in the Netherlands (TU Delft) to produce publications and collaborate on product sustainability projects. D4S is a unique methodology because it not only encompasses all three pillars of sustainability (people, profit, and planet), but it also is applicable to supporting sustainable production capacity in developing countries. This article will highlight key concepts and D4S approaches and will discuss a recent D4S initiative, the Cleaner Production for Better Products (CP4BP) project. In addition, several case studies will be presented to shed further light on concepts and strategies of sustainable product design.

2. Background

For a better understanding of concepts and players implementing D4S, some contextual and background information is presented below.

2.1. Sustainability Initiatives

Sustainable innovation and design is not necessarily about new technologies, but about rethinking how to meet the need for growth while at the same time reducing negative environmental and social impacts. This concept, known as "decoupling", is of great importance as it seeks to break the link between economic growth and environmental degradation [1]. Decoupling is an idea largely associated with industrialized countries; 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. While these processes have been successful in helping industry in these nations improve production efficiency, they have largely ignored practical applications in the developing world. Industry is vital for the economic growth of all nations, but developing countries operate with much different circumstances and needs that should be taken into account [2]. Sustainable innovation allows for leapfrogging in production and design processes to make it possible for these newly industrializing countries to achieve decoupling in the beginning, not the end, of the industrialization timeline. Mere production efficiency increase does not, of course, translate into absolute environmental benefit, but cleaner production processes are an essential component of a widespread movement of sustainable design that could challenge entrenched consumption and production patterns.

Cleaner Production

In 1989, in response to a growing realization of rapidly increasing pollution costs, UNEP began to work on approaches to prevent pollution from occurring in the first place. The resulting strategy, Cleaner Production (CP), is defined as "the continuous application of an integrated preventive environmental strategy to processes and products to reduce risks to humans and the environment [3]". The strategy has been proven to be cost-effective, is being used in many forms all over the world, and has evolved to cover areas such as energy efficiency, multilateral environmental agreement targets, and sustainable products (including D4S).

Design for Sustainability

D4S is an ecodesign concept that has evolved to include both the social and economic elements of production. It integrates the three pillars of sustainability - people, profit, and planet, but goes beyond simply "greening" products to embrace how to meet consumer needs in a more holistic, sustainable way [4]. It also is unique in that it can focus specifically on the needs of industry in developing countries. Companies incorporating D4S into long-term product innovation strategies strive to alleviate the negative environmental, social, and economic impacts along a product's supply chain and through its life cycle—the "cradle-to-cradle" mentality.

While these drastic changes can present formidable challenges, there are encouraging developments that contribute to the expanding knowledge base of sustainable product development. These newly designed products and services offer increased functionality and ease of use, longer life spans, easy disassembly or recyclability, lower environmental impacts which can save the company money, and improved materials sourcing and production which can positively affect communities. In other words, sustainability offers added value through better quality and lower price—the two motivators for most consumer decisions.

D4S can be used in small- and medium-sized enterprises (SMEs) in developing countries, which have economies that offer few incentives or support for innovation. For example, the economy in South Korea in the 1960s was based on low-tech copying and product imitation; by incorporating product innovation into its overall development strategy, it has produced a high level of innovation capacity and is now an internationally competitive, pioneering economy [4].

2.2. D4S Implementing Partners

United Nations Environment Programme, Division of Technology, Industry and Economics

UNEP encourages local and national authorities, alongside industry, to develop and implement policies, strategies and practices that are cleaner and safer, reduce pollution and risks for humans and the environment, and incorporate environmental costs. UNEP has taken an active role in the sustainable product field, developing innovative approaches and testing and replicating best practices. In 1997, UNEP published "Ecodesign: A Promising Approach to Sustainable Production and Consumption [5]", which introduced the fundamental concepts of ecodesign to policy makers, designers, and company managers.

On the operational level, UNEP developed a targeted methodology that is detailed in the publication *Design for Sustainability: A Practical Approach for Developing Economies*. The manual, which focuses on various D4S innovation strategies that improve the capacity of SMEs in developing economies to increase product sustainability, was developed in partnership with TU Delft, ecodesign experts, and InWEnt, Capacity Building International (Germany), based on testing and evaluation in several developing countries using a network of National Cleaner Production Centres (NCPCs) [4].

Faculty of Industrial Design Engineering at TU Delft

The D4S programme within the faculty of Industrial Design Engineering at TU Delft focuses its activities on sustainability issues connected to product design. The exploration of opportunities to innovate and design products and services with respect to sustainable development values is a key concern for the Institution, and is the central driver of the D4S programme. Attention is also given to fitting design and marketing of products and services for the vast potential markets in Latin America, Africa and Asia, both by multinational companies and by SMEs worldwide.

UNIDO/UNEP Programme of National Cleaner Production Centres

The UNIDO/UNEP NCPC programme was established in 1994 by the United Nations Industrial Development Organisation (UNIDO) and UNEP to build local capacity to implement CP in developing countries and economies in transition. The programme is based on the premise that CP can be integrated into a country's industries and policies only if local capacity exists to sustain it. While UNIDO is in charge of administration, UNIDO and UNEP both provide expertise, training, information and policy analysis [6]. By continuing to focus on building institutional capacity in developing countries, UNEP and UNIDO are laying the groundwork for long-term habit change.

3. Design for Sustainability: Approaches to Innovation

Product innovation is instrumental for economic growth. Successful innovation is the driver of competitive advantage and, along with sustainability, forms the core of the D4S methodology. Industries in developing countries engage in different levels of innovation as a strategy for economic growth, so D4S is designed to include a wide range of approaches that can be tailored and applied to improve the efficiency and social qualities of products, services, and systems. Hence, in addition to incremental innovation, D4S also encompasses radical innovation approaches that target new product development and Product-Service Systems (PSS), which challenge current consumption and production patterns by completely re-thinking products in light of consumer needs [4]. These product system innovations are designed to create win-win solutions for businesses, local communities, supply chains, the environment, and consumers.

The D4S research programme includes the systematic development, testing, and international diffusion of methods and tools for the design of products with superior life cycles, improved eco-efficiency and effectiveness (via intelligent materials and energy applications, integration of emerging product-technologies, and economic optimization). The focus is on modeling, actual application, and demonstration of sustainable products, departing from simply an engineering/life cycle design perspective.

The challenges for D4S are to generate knowledge supporting the innovation and design engineering of products and service systems with superior sustainability and to make optimal use of networking and entrepreneurship as success factors for implementation.

The key D4S approaches are: redesign and benchmarking (incremental design), and new product design and PSS (radical design) [4]. The first two design approaches are particularly relevant in developing economies where product innovation capacities are low and many products are designed

based on copying/benchmarking existing products. However, radical innovation in new product and service design offers great potential in realigning the consumption and production patterns of nascent industries.

3.1. Redesign

The goal of D4S redesign is to sustainably redesign an existing product for which the specific market and manufacturing conditions are already known, taking into account its primary function and the associated services provided. A product's improvement potential can be determined relatively easily as the product already exists, so market and manufacturing information is readily available. D4S redesign is of particular interest to developing countries as this more incremental type of innovation requires smaller risks and investment and follows a structured and predictable path, but can be just as important as a more radical approach in terms of economic and environmental impacts.

The redesign process uses a project team to harness both outside expertise to incorporate sustainability aspects into products, but also company employees who can often provide valuable insight. When choosing an initial product for redesign, companies should focus on the interventions that have the potential for greatest impact while being simple and timely to implement, and in line with overall company goals. The finished, redesigned product should be compared against the initial product to consider and estimate the sustainability advantages of the new product versus the original; after the product is launched, the company must do follow-up to evaluate overall sustainability, which will spawn new implementation ideas for future products [4].

Redesign Case Study: Wai Tui, Fiji

Wai Tui is a small clothing label in Fiji that produces a variety of surf wear bearing locally-inspired motifs and designs. Its parent company, APM, produces textiles for other companies as well as for Wai Tui. In 2003, the Integrated Solid Waste Management project at the Pacific Centre for Environment and Sustainable Development at the University of the South Pacific, Fiji was launched with the goal of finding sustainable ways to reduces solid waste by increasing industrial sustainability. In order to better understand the potential for D4S in a Small Island Developing State (SIDS), the project began a case study in partnership with Wai Tui in September, 2007, with a seven member team composed of representatives from a variety of departments, including production, quality control, printing, and sales. The team reviewed Wai Tui's portfolio of products and decided that a backpack was appropriate for D4S Redesign due to several reasons, including its simple design, high sales volume, and competitive market [7].

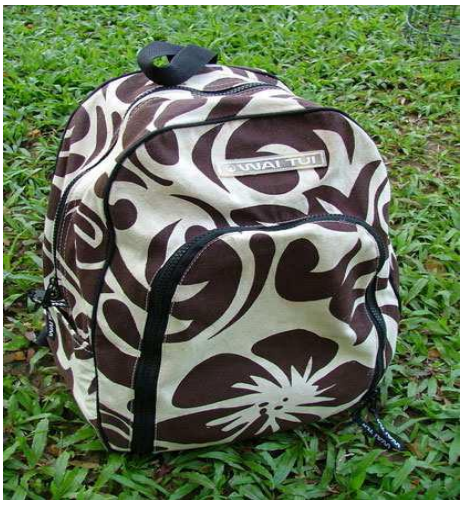
The main drivers for this project were the development of new markets, increased exports and increased competitiveness. The design team focused on materials, human resource management and solid waste as priority impact criteria to target, and achieved the following results:

- Packaging reduced by 75%,
- Polyester replaced with cotton fabric,
- Water-based paint used for screen printing,
- Improvement in the safety in the factory,

- Reduction of electricity of the air compressor by 50%, and
- Decrease in the amount of paper used by 30%.

The project resulted in a backpack that will have less impact throughout its lifecycle on the fragile SIDS ecosystem (Figure 1), and that has provided a useful illustration of D4S redesign.

Figure 1. Wai Tui's organic cotton backpack. The redesign uses eco-friendly materials and packaging.



3.2. Benchmarking

Benchmarking and other approaches based on replication are still the predominant way in which products are designed worldwide—in developing and developed countries alike. The goal of D4S benchmarking is to learn from the best practice of competitors by comparing one's product to those of competitors to determine how to make that product more sustainable [4]. The methodology is a structured approach in which improvement options are generated by looking at the environmental, social, and economic aspects of a particular product. Benchmarking differs from D4S redesign in that it starts with comparing existing products in the market before moving into the design phase. Like redesign, D4S benchmarking also uses a project team to decide the goals for the process including, but not limited to, entering new markets, improving competitiveness, and making environmental improvements.

Benchmarking Case Study: Waiman Industries, Costa Rica

Industrias Waiman, located in San Jose, Costa Rica, produces metal products and appliances to heat, cool, and prepare food and beverages. The company consists of an owner-manager and eighteen employees. In 1999, the company began a D4S project with the main objective to develop a product that would improve sales but have fewer environmental impacts. To do so, the company chose to benchmark a commercial refrigerator against its main competitors' products. The priority was to improve cooling efficiency of the product, and at the same time reduce energy costs.

The company gathered information from brochures and the internet on the price, market share, and technical specifications of competitors' products. Next to this, the local refrigerator market was

analyzed, with a focus on food and beverage company needs. The results, tested and applied on the new Waiman refrigerator prototype, included:

- Shorter time needed to lower the temperature,
- Better distribution of the cooled air by repositioning of the ventilator,
- Door resistance eliminated to decrease energy use,
- Exhaust heat used to heat the outside window to reduce condensation, and
- Repositioned lighting to improve efficiency [8].

3.3. New Product Design

The D4S new product development approach applies "out-of-the-box", or radical, innovation strategies, which can lead to more sustainable impacts while providing the breakthroughs necessary to ensure an company's continued competitiveness. New product development involves a higher level of technical, market, and organizational uncertainty than redesign but can be an inventive and iterative process where new ideas on how to meet needs are converted to products and services [4]. Eco-friendly materials, sustainable development practices, and innovative information and communication technology are all concepts that can help inspire new product design. As consumer needs and expectations evolve, new products and services offer opportunities to enhance product portfolio sustainability including addressing increasingly important social concerns.

The stages and processes involved with new product design can be viewed as three-fold: policy formulation, idea generation, and product development [4]. Policy formulation addresses the company's goals and strategies; idea generation allows the company to brainstorm and develop ideas for new products, taking into account the ability to harness developing technologies, materials and consumer needs; and finally, product development involves debating and testing concepts against the decisions in the idea finding phase. The key challenge with respect to new product design is market demand. Without a consumer need, even the most sustainable product will fail.

New Product Design Case Study: Kamworks, Cambodia

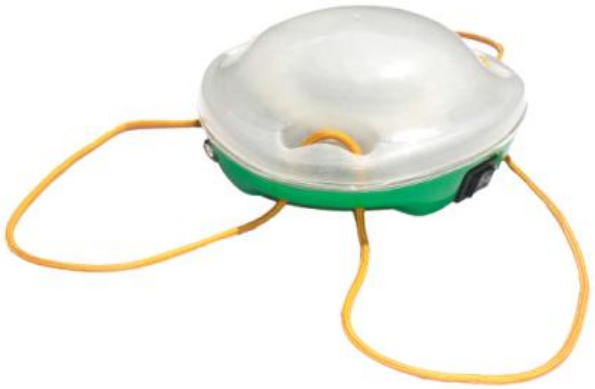
Kamworks is a startup solar company in Cambodia founded by the Dutch charity foundation Pico Sol in 2006. Cambodia receives on average five full solar hours a day, so Kamworks saw the country's solar capacity as an opportunity for local production of solar lighting products that fit the purchasing power of rural households [9]. After an initial analysis and development of a solar lantern, Kamworks contacted TU Delft to work on a series of projects that covered the total design phase of a mobile lighting product from market analysis to final prototype.

Many people in Cambodia use kerosene fuel lamps as a mobile light for purposes in and out of the house. The light is not very bright, the lamp cannot be used in windy or rainy conditions, and fuel costs are exorbitant. For the most recent Kamworks lighting project, the goal was to provide a sustainable lighting solution for low-income rural households, the vast majority of which do not have access to the public electricity grid. In order to design a product that could be manufactured locally, but that also met the needs of a diverse group of people, an "Integrated Design Project" was carried out in rural Cambodia. The design team came up with several recommendations, including the need for a durable,

shock-proof lamp that was portable and could completely replace the traditional kerosene one. On the basis of this data, a series of possible new designs for lamps was developed, and the "MoonLight" was chosen as the final prototype [10].

The final design has a triangular shape and includes a cord that is attached at the three corner points (Figure 2). It mainly consists of two vacuum-formed outer shells and two also vacuum-formed blisters that hold the electronics together and buffer them at the same time for possible shocks can be hung from wall or ceiling, carried by hand or hung around the neck, and has six wide-angle LEDs, which give equivalent light output of about four kerosene lamps. It comes with a solar panel for easy charging [10]. The product's ease of use and simple design gives Kamworks high hopes that the MoonLight could be revolutionary in rural Cambodia.

Figure 2. The Kamworks prototype "MoonLight". The design is intuitive and easy to use.



3.4. Product-Service Systems

PSS illustrate the movement from ecodesign to D4S because they use different ways of addressing at the design stage what a customer really needs and the way a product is designed, produced, used and discarded. PSS can be an effective function-based strategy that concentrates on "satisfaction" as a product value instead of private ownership of physical products, a traditional standard of well being that exists in many industrialized contexts [11]. Sustainable innovation and design is not necessarily about new technologies, but about rethinking how to meet everyone's needs of sustaining growth without costly environmental and social impacts.

PSS already exist in today's society, especially in developing countries. Often these systems are a way of life, and are not perceived of in the sustainability context (Figure 3). In many developing countries where different members of a society cannot afford to own products, they divide the product to maximize the benefits amongst a wider group. These examples of PSS can be useful as illustrations, but the challenge is to find the benefits in cross-sharing of experience between developed and developing countries.

Figure 3. The table below outlines differences between traditional product sales and Product-Service Systems [12].

Traditional product sales	Innovative alternatives: Product-Service Systems	
Consumer buys a washing machine to clean cloths in house/hotel.	Consumer rents a washing machine to clean cloths in house/hotel.	Client buys a service from a company (laundry) to clean cloths (Company determines best equipment and methods based on client's needs).
Client owns, uses and stores washing machine. Consumer is responsible for maintenance and the 'quality' of the cleaning.	Company retains ownership of washing machine and is responsible for maintenance. Client is responsible for use and 'quality' of cleaning.	Company owns, maintains and stores the cleaning equipment including washing machine. Company is responsible for 'quality' of the cleaning.
Initial investment for consumer could be considerable.	Consumer costs are spread over time (they pay a low initial deposit and then pay per wash).	Consumer costs are spread over time (they pay per wash).
Consumer ultimately disposes of washing machine and buys replacement.	Company is responsible for disposal and has incentives to prolong use of product, reuse component and recycle materials.	Company is responsible for disposal and has incentives to prolong use of product, reuse component and recycle materials.

Product-Service Systems Case Study: Tourism Sector Potential

A key application of PSS with great potential for sustainable change is in the tourism sector. In 2004 the global sector had over 764 million international tourists and generated over 500 million Euros in revenue, but also has major environmental impacts, and is currently responsible for 5% of climate change emissions [13]. The accommodation sector has a tremendous opportunity to invest in renewable energy and energy efficient solutions that cut operational costs; research shows that by applying such available technologies the sector can reduce its carbon footprint by more than 30% with payback periods of less than a year in some cases [13].

Rethinking a tourism product to reflect the uniqueness of a destination, including pristine mountain landscapes, local foods and authentic culture can drive more sustainable land use planning, tourism policies and local community inclusion, where development is closely linked with the tourism sector. In a recently implemented project, UNEP, in partnership with the European Commission, the Nepal Tourism Board, and SNV (a Dutch development organization), worked with 23 committed small- and medium-sized tourism companies to redesign tourism products to make them more sustainable and to better target a growing European market.

The project had four goals to improve the sustainability of products:

- Building company capacities through action planning,
- Reducing environmental damage related to the selected tourism products and operations,
- Integrating poverty alleviation aspects into redesigned products, and
- Using marketing mechanisms to promote, motivate, and reward sustainable tourism.

One company, the Syangboche Panorama Hotel, which offers accommodation and trekking in the Everest region, redesigned their product to improve environmental sustainability by evaluating resource use. The company noted the importance and scarcity of water, taking into account the resource needs of the local community, and constructed a rainwater harvesting system for their hotel. They also evaluated their purchasing practices and developed and implemented a policy geared to supply local and organically grown food products to support the local economy and to reduce the company's waste stream [13].

Redesigned tourism PSS yield environmental and social benefits, but more importantly they create new synergies between companies and local communities to conserve the environment and improve the quality of life of the people, which in turn helps boost the tourism trade. Tour operators and travel agents also have enormous power to raise awareness among customers on climate change and to engage them in the response process. Through responsible choices in their supply chains they can implement carbon neutral practices and send the message that sustainably designed tourism offers a competitive advantage.

4. Cleaner Production for Better Products

In 2007, the Vietnam Cleaner Production Centre, in collaboration with UNEP DTIE and TU Delft, began a project with financing from the European Commission Asia Invest Programme called Cleaner Production for Better Products (CP4BP). The project's objectives were (1) to increase the capacity of select industries in Vietnam, Cambodia and Lao PDR to develop eco-friendly and socially responsible products for the European market and (2) to create trade opportunities between the three countries and Europe. In addition, the project was designed to promote the uptake of CP and D4S methodologies. Thus, CP4BP can be seen as an application of the evolution of CP and D4S, as it pushes for uptake of both strategies at the same time and in a complementary way.

The project consisted of three phases: start-up and training, pilot projects and studies, and finalization and dissemination. The first phase involved country assessments to identify target sectors and products in the participating countries and to integrate existing D4S resources into the project. Training-of-trainer workshops were also held for technical service providers and industry representatives in the three countries. During the second phase, which lasted approximately 11 months, the project enlisted seven Vietnamese SMEs in the furniture, fishing and handicrafts sectors to demonstrate the benefits of CP4BP approach and conducted research to determine feasibility of future applications of the CP4BP approach at a larger scale. At the end of the pilot project phase, the project partners held sector-specific trainings as well as dissemination workshops of project findings in various locations in the three countries.

The project generated an overwhelmingly positive response. The training programme had double the anticipated demand for company participation, and some participating companies, seeing the potential of using sustainability as an added value to sell the products and to save money, have designed entirely new product lines that will be on the market this year.

The three subsections below highlight case studies from each of the three CP4BP industrial sectors: furniture, fisheries, and handicrafts [14]. Following the case studies is a review of overall lessons learned.

4.1. Xuan Hoa Furniture Company: Developing a Modern, Sustainable Style

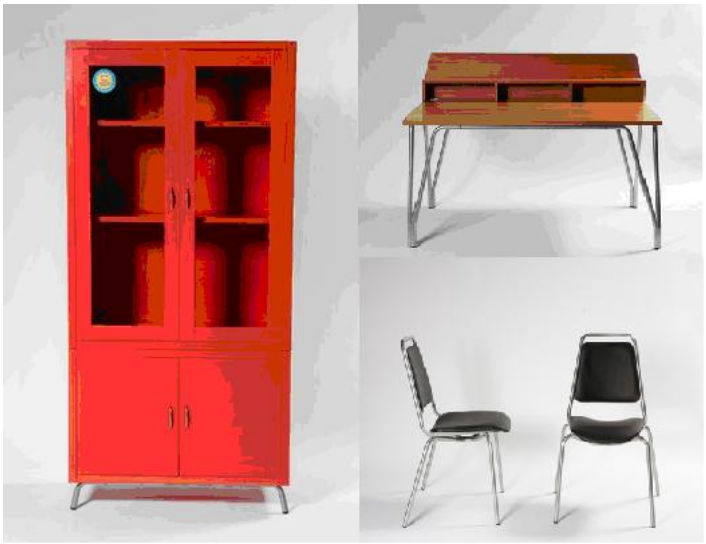
Xuan Hoa, one of Vietnam's leading industrial companies, began as a bicycle manufacturer; today it employs 890 workers and has expended its activities into furniture production. The company uses leading-edge technology and equipment, employs qualified and experienced people, and has continuously made high quality products that have won medals at international and local trade fairs.

The company's interest in participating in the CP4BP project was driven by the vision to increase exports to international markets by integrating sustainable product design and development capacity with increased innovation throughout its factory. Xuan Hoa has worked with the Vietnamese NCPC for several years, so it was a natural fit for the company to take on CP4BP.

Xuan Hoa Product Development

The Project Innovation Team was made up of 12 company staff members and eight CP4BP experts. The project assisted the company in building-up their capacities in sustainable product development. Although the uptake of the concepts was slow, the company dedicated itself to using D4S to develop a new 14-piece product line that adopts modern styling and advanced technology (Figure 4). In addition, the company significantly improved two existing product lines, desks and wardrobes, by reducing costs and improving quality. In addition to product design and development, the company also made effort to improve the packaging of some products.

Figure 4. Examples from Xuan Hoa's new, sustainable furniture line.



Xuan Hoa Lessons Learned

The two project teams initially found it a challenge to understand the D4S method, as it was delivered through a formal "top-down approach", meaning that concepts were given through study of theory; the teams decided that a "learning by doing" pedagogical approach would be more effective. The company management and project innovation team members agreed that the project's methodology is very interesting and are waiting to see commercial success before evaluating the approach's effectiveness.

4.2. Hung Ca Seafood Company: Efficient Packaging and Resource Consumption

Hung Ca is a newly established Vietnamese company that cultivates and processes fish and shrimp. The company employs 1,200 workers and exports to Japan and Europe; its main product is pangasius fish (a type of catfish), a typical product of the Mekong River delta. Through the support of the CP4BP project, Hung Ca has plans to promote more sustainable aquaculture products. The company has a modern production line which has good potential for applying such CP concepts as separating waste streams to reduce water treatment, saving energy and optimizing equipment use.

Hung Ca Product Development

The Project Innovation Team was made up of nine company staff members who were divided into two groups: one group focused on improving production processes and the other was responsible for market research, marketing and product innovation. The two groups met once a month and were in continuous contact with each other. Five CP4BP experts worked with Hung Ca's Project Innovation Team, and their efforts were focused on packaging design and electricity consumption. The company achieved the following results:

- Changed packaging to accommodate more fish as well as to allow more boxes to be stacked on each transporting pallet. By optimizing package size the company increased the amount of product per container by 2.2%, achieving a cost reduction of $24 per pack.
- Installed an electric and water meter system and insisted on good housekeeping methods, which achieved a reduction of water consumption by 32.4% and electricity consumption by 4.9%.
- Bought integrated software for production management to support process optimization.
- Identified new product lines such as spiced shrimp and fish and vegetable skewers that target European tastes.

Hung Ca Lessons Learned

The company has shown dedication and commitment towards the uptake of the CP4BP concepts and notions, which have produced positive results and major cost savings. The delivery of initial positive outcomes has spurred the company's eagerness to continue undertaking CP and designing further methodologies for improvement.

4.3. Hoa Son Handicrafts: Building Capacity for Product Development and Improvement

Hoa Son is a small company located in the village of Phu Vinh, Vietnam, where the handicraft tradition is over 500 years old. Hoa Son products are primarily rattan, bamboo, and fern woven objects, and its 125 local craftsmen dedicate part of their domestic time to production. The process uses many chemicals, including color dye-stuffs, paints and sulfur for material pre-treatment and preservation. In the past, the traditional products were made without chemicals. However, due to the advantage of shortening the production duration and costs, the company has increasingly used chemicals in place of natural dyeing and processing methods. By participating in the CP4BP project, Hoa Son hoped to enter

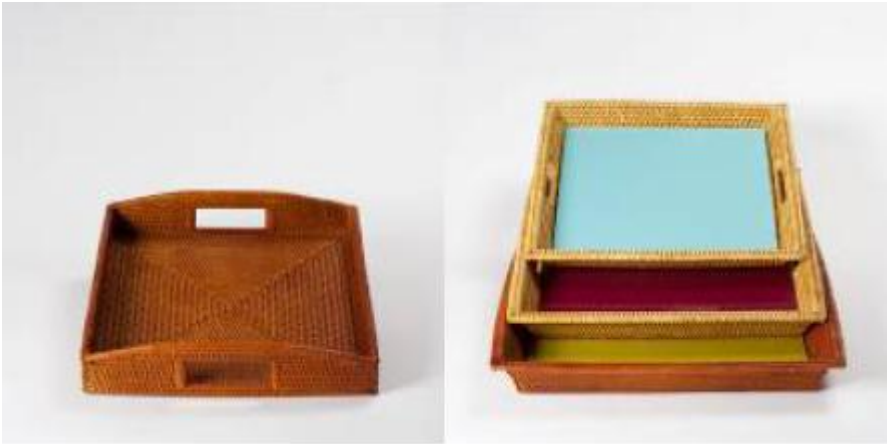
and expand into new markets by improving design capacity and to include environmentally sustainable principles in production, thereby boosting marketing capacity.

Hoa Son Product Development

The Project Innovation Team included three company staff members and the company director along with Eight CP4BP experts. The project assisted the company in building up their capacity for sustainable product development, with notable achievements including:

- Creation of ten new naturally dyed color samples.
- Improvement of five existing product samples with the aim of reducing the packaging and transportation costs. As a result, the new products can easily be stacked and transported.
- Reduction in use of rattan, which is becoming scarce; the base of one product, a tray, is now made in lacquer (Figure 5).
- Pilot testing of five new product samples in European and Australian trade fair exhibitions. These products used less materials, used less or no water and no pre-processing chemicals.
- Upgrade of lighting conditions for workers.

Figure 5. Before, the tray was made of 100% rattan; the company replaced the base of the tray with lacquer, thus reducing the amount of scarce rattan used.



Hoa Son Lessons Learned

The CP4BP process caused excitement within the company, and employees agreed that the clear, elaborated, step-by-step guidelines from the experts were essential to easy uptake, as the support was practical, not theoretical. Important demonstration results were achieved by mixing D4S methodology and traditional rattan-bamboo production techniques. However, the need for developing more specific D4S manuals for the rattan and bamboo sectors has emerged, and Hoa Son will be involved in a new project in the rattan sector so as to be able to continue D4S development activities and CP implementation.

4.4. CP4BP Lessons Learned

The project was a success, and it underscored D4S as a valid concept that can bring improved financial prospects and at the same time result in environmental and social improvements. However, integrating sustainability remains a challenge for companies and the intermediaries that work with them. Some of the lessons learned are listed below:

- The D4S approach should be more streamlined to increase uptake in more industrial sectors.
- SMEs need technical, not just theoretical, support to develop sustainable innovation capacities that achieve best results in terms of added product value. Informal networks like the one developed in CP4BP and integrated with other sustainable product related initiatives are a good start.
- Resources and commitment at the company level are vital components for success.
- SMEs must realize that D4S is not a one-time or short-term effort, and that creating sustainable products can span product generations.
- More sustainable product marketing support is needed to better understand consumer needs and translate them into new products and services.
- Developing a supportive D4S policy context that keeps in mind on-the-ground realities is a remaining challenge.

The CP4BP project, while relatively small in scope, was crucial in delivering practical information on how to better apply D4S. The next challenge is to better integrate D4S to cover technical issues and supportive policy frameworks, a process which will require sustained commitment from all stakeholders.

5. Conclusions

Key stakeholders have come to view CP, D4S and other forms of sustainable product design as offering significant opportunities to shift global consumption and production patterns to a more sustainable model, given their potential in theory and practice.

Benefits of employing the D4S methodologies in the developing country context were illustrated in the previously presented case studies. These case studies explored topics from product redesign to radical innovation, and the three pillars of sustainability, people, planet, and profit were highlighted. D4S aims to address all three of these pillars in a complementary way to improve not only the environmental aspects, but also the social and economic impact, of products, systems, and services. New initiatives like CP4BP show how relatively small amounts of funding and expertise can spur radical changes in ingrained production practices, and can be extremely cost-effective.

Above all, the case studies were made possible because they had the necessary commitment and dedication from key stakeholders, including those within the companies, to bring about real change. D4S concepts are not hard to understand, but changing entrenched habits remains very difficult. There is no doubt that promoting D4S in developing-nation companies will require more work; however, the awareness of the need for radical shifts is heightened, and projects such as CP4BP can provide much needed case studies to assist the transition. These types of programmes are especially important in developing countries, which have the opportunity to use both technology and international expertise to decouple unsustainable patterns of consumption and production. Changing these patterns through the

design of new, sustainable goods and services is part of a more sustainable future, and businesses that want to become or remain competitive will need to address these issues to succeed.

As noted before, just making production more sustainable does not guarantee environmental benefits. For example, a large increase in production efficiency coupled with a similar increase in overall production would mean no absolute environmental gain. If complemented with more sustainable personal lifestyle choices, cleaner production practices could be a key factor in a revolution in production and consumption patterns. As noted in the case studies above, much of the drive for improved production methods comes from consumers, especially in developed countries, who have the luxury to demand these types of goods and services and who are helping to spur industries in developing countries to adopt various ecodesign methodologies.

As John Ehrenfeld notes in *Sustainability by Design*, sustainability is defined as "the possibility that humans and other life will flourish on the Earth forever [15]". We still have the opportunity to change our unsustainable habits, but we can no longer afford to take our current consumption patterns for granted. A consumer demanding cleanly-produced products might feel good about his or her lifestyle choice, but it will take more than just consuming such products to initiate a change – it will require a decrease in consumption as well in order to realize any gains. The initiatives discussed above, as illustrated by the case studies, provide examples and experiences to inspire action and commitment to move forward, not just for producers but for the consumers who demand action but have hitherto absolved themselves of responsibility for pollution and climate change. D4S, like the environmental movement, is a concept in evolution, and UNEP, TU Delft, and their partners look forward to continuing to help developing countries implement sustainable production strategies to inspire new thinking about the entire circle of production and consumption.

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