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A CLASSIFICATION OF RESEARCH ON "GREEN DESIGN": THE JOURNEY TO SUSTAINABLE PRODUCT-SERVICE SYSTEMS

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Abstract

The issues related with 'green design' have been drawing an increasing attention for the last three decades. We are becoming more aware that the resources of the world are not limitless and we have to take more environmentally friendly routes on our endeavours for our future generations to survive. In this study, a brief literature review on 'green design' is provided by making use of a basic classification scheme that illustrates the recent concentrations of research on the concept. Through this classification, the development of research in the field and the stages it has gone through will be presented and a currently popular and relatively fertile area `sustainable product-service systems` will be described. Some research gaps will be identified and future research directions will be given.

Keywords: Green design, sustainable product-service systems.

Öz

"Yeşil Tasarım" Konusundaki Araştırmalar Üzerine Bir Sınıflandırma: Sürdürülebilir Ürün-Hizmet Sistemlerine Giden Yolculuk

Son otuz yıla baktığımızda 'yeşil tasarımla' ilgili konuların gittikçe daha fazla ilgi çektiğini görebiliriz. Dünyamızın kaynaklarının sınırsız olmadığı göz önüne alındığında, gelecek nesillerin varlıklarını sürdürebilmeleri için çevreye duyarlı yaklaşımlarda bulunulmasının gerekliliği oldukça açıktır. Bu çalışmada, son yıllarda konuyla ilgili yapılan bilimsel araştırmaların yoğunlaştığı alanları gösteren bir sınıflandırma verilmiş ve bu yolla 'yeşil tasarım' hakkında kısa bir literatür taraması yapılmıştır. Bu sınıflandırmayı kullanarak, araştırmaların alan içindeki gelişimi ve geçirdikleri aşamalar belirtilmiş ve son dönemlerde popüler ve verimli bir araştırma konusu olan 'sürdürülebilir ürün-hizmet sistemleri' tanıtılmıştır. Yapılan araştımalardaki bazı fırsatlar gösterilmiş ve gelecekteki yeni araştırmalar için bazı doğrultular verilmiştir.

Anahtar Sözcükler: Yeşil tasarım, sürdürülebilir ürün-hizmet sistemleri.

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INTRODUCTION

We are becoming more "green". For the last three decades or so, environmental issues have gained significant importance and are drawing a rapidly increasing attention. We are demanding and using more ecological products and seeking more environmentally friendly answers to our problems. The words such as ecology, environment, green products, eco-design, and recycled materials are becoming more and more familiar in our everyday language and we can encounter more instances of them in the media. We are becoming more environmentally aware and beginning to take account of these concerns in many aspects of our lives.

This popular trend can be deemed to be fairly young. It only dates back to the beginning of 1980s. It was around those times that humanity became aware of the fact that the resources of the world were limited. The depletion of natural resources like forests and raw materials, increasing water and air pollution levels, growing amounts of industrial waste and garbage, uncontrollable rise in energy demand, global warming and exponentially rising population of the earth have alerted us that the assets of the world were drying up quickly, and unless urgent precautions have been taken, the future generations would face up with a completely depleted and exhausted world that will put the survival of human race into a significant danger.

Through this recognition, starting from the 1980s, a new era of increased concern and awareness about the environment has begun. This new era is acknowledged to have initiated after the influential Brundtland report that was published by the UN World Commission on Environment and Development in 1987. In the report, the term "sustainable development" was defined as the development that can meet the needs of the current generation without putting the needs of the future generations into danger (Burall, 1991:15; Baumann et al., 2002: 420; van der Zwan and Bhamra, 2003: 897). From that time forward, the world has experienced a significant shift in its perceptions about the way products are designed and produced, as well as the way business is managed and regulated. The utilized raw materials, the consumed energy and the generated waste are strived to be reduced and there is an intense effort to minimize the ecological degradation and the associated health risks (Baumann et al., 2002: 413-421).

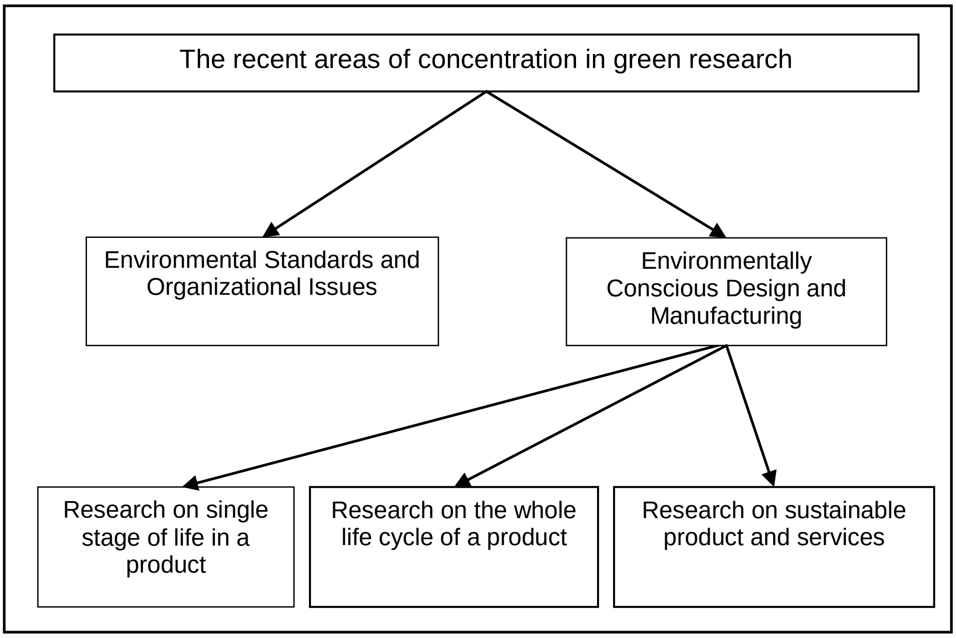
The academia has likewise shown an increasing interest so that the amount of research on the matter has attained a steady growth. There are now dedicated journals on the area such as Journal of Cleaner Production, Ecological Economics, Journal of Environmental Planning and Management, Resources Conservation and Recycling, and Environmental Management. The area of applicability has also surpassed its initial points and now enjoys a multidisciplinary interest with a wide range of applications in the fields of food and chemistry (e.g. Gerbens-Leenes et al., 2003: 231-248, Stoughton and Votta, 2003: 839-849; Evans et al., 2007: 4225-4246; Kelemci-Schneider and Somtürk, 2008: 1-18; Li, Zhang et al., 2009: 233-243), architecture and construction (e.g. Grant, 1997: 75-78; Potts Carr, 1998: 239-257; Reed, 2007: 674-680; Rajendran et al., 2009: 1058-1066), textiles (e.g. Nimon and Beghin, 1999: 1078-1083), metallurgy (e.g. Marukawa and Edwards, 2001: 133-136; Graedel, 2002: 107-115), computers and electronics (e.g. Hersh, 1998: 497-510; Ciocci and Pecht, 2006: 45-50; Nie et al., 2007: 4-9), tourism (e.g. Sasidharan et al., 2002: 161-174; Chan and Wong, 2006: 481-492) and agriculture (e.g. De Snoo and van de Ven, 1999: 179-184; Reith and Guidry, 2003: 219-229) to name a few.

In this paper, the primary aim is to briefly review the subject broadly known as the “green movement” or “green design” by providing a basic classification that illustrates the concentrations of research in recent years. Through this classification, a currently popular theme, `sustainable product-service systems` will be described. It must be noted that the purpose is neither providing a highly detailed and complete review on this vast subject nor presenting an all-encompassing and unique classification scheme, but to draw attention to the prominent concept of sustainable product-service systems by highlighting its development and the stages it underwent embedded in the classification provided. At the same time, the research gaps in this literature requiring more refined and more elaborate studies will be pointed out. In this respect, the ultimate motive is to make a strong call for Turkish academicians to conduct future research on this area which will be instrumental for developing environmentally conscious product and service oriented ventures in Turkey.

1. THE CLASSIFICATION OF “GREEN” RESEARCH

In Figure 1, a basic classification of research on green design is presented based on the publications in recent years.

Figure 1: A Basic Classification of Recent Research on Green Design



This classification scheme suggests that recent research practices on green design have been conducted mainly in two categories. Overall, the first category of research is on business administration that examines the environmental standards and the implications of green issues on the management and economics of a firm. The research on this branch also deals with the transformation of business from the classical approach to an environmentally aware one.

The second category in the classification contains studies that rely more heavily on environmentally conscious products and their manufacturing. This category is relevant to the operations practices in the field and includes the design, production and evaluation of green products, services and the associated methodologies.

The work conducted in this category can be further classified into three groups. This sub-classification (provides) not only a content wise categorization but also a glimpse of the historical development and the stages the field has gone through in its way to maturation. The first category includes research that focuses on a single stage in product’s life cycle such as waste management or recycling. This category was the primary focus during the initial expansion stages of this literature. Then came the second category which concentrates on the whole life cycle of a product. It was recognized that focusing on a single stage was not enough for a green breakthrough, so that for significant development, the whole life cycle of a product from "cradle to grave" (Hanssen, 1999: 27) has to be considered and evaluated. Starting from the end of 1990s, life cycle methodologies have matured into the larger and comprehensive perspective of "sustainability". Even though sustainability as a word has been used in the area since the beginning, it has become the defining word for this latest trend in green design. These systems claim that for achieving sustainability redesigning the products was not enough. The whole system, perceptions and lifestyles of the society have to go through a significant change so that a major breakthrough in terms of environmental consciousness could be achieved.

In the following sections, I shall provide more details pertaining to the categories in this classification.

1.1. The Research on Environmental Standards and Organizational Issues

The importance of environmental standards and regulations is frequently mentioned in the literature (Glantschnig, 1994: 510-512; Hanssen, 1999: 39-40; van Hemel and Cramer, 2002: 439-453). World governments or international organizations should provide a set of standards and regulations so that the companies and industries will be encouraged to take the necessary precautions to integrate environmentally conscious philosophies into their areas of business. In this way, these standards and regulations will act as external stimuli and provide useful guidelines for transforming into a green society (van Hemel and Cramer, 2002: 441-442). Hanssen (1999: 39) stated that the society expects the environmental policies and standards to act as catalysts in providing cultural shifts on resource consumption patterns and increasing the innovation capacity in the society. They are also anticipated to improve the material and manufacturing efficiency of products and to enhance the flow and exchange of information within the society. In order to realize these expectations, two of the recognized methods are "ecolabels" and the currently evolving ISO 14000 environmental management standards.

Ecolabels, in general, are special logos that are shown on the products signifying that the product conforms to a set of environmental standards. Nearly everyone is aware of the widely used recycling logo that is in the shape of a triangle formed from three curved green arrows (Burall, 1991: 61-65). Another common ecolabelling scheme is used in computers for signifying energy efficiency. The "energy star" of US EPA (Environmental Protection Agency) and the "blue angel" of Germany are nice examples for this case (Hersh, 1998:

499-500; Ball, 2002: 424-425). The ecolabels can also find areas of application in tourism (e.g. Sasidharan, Sirakaya and Kerstetter, 2002: 161-174; Boevers, 2008: 524-531), agriculture (e.g. De Snoo and van de Ven, 1999: 179-184), food (e.g. Pelletier and Tyedmers, 2008: 918-931) and textile sectors (e.g. Nimon and Beghin, 1999: 1078-1083).

As the above examples designate the ecolabels are generally limited in content and usually point to a single aspect of the environmental issues such as recycling or energy efficiency. Moreover, they remain as regional standards on most occasions. Due to these deficiencies, there was a clear need for a comprehensive approach that can achieve international acceptance.

For this purpose, the International Organization for Standardization (ISO) has developed ISO 14000 family of standards in 1996. These standards attempt to provide a practical set of tools and guidelines to assist companies in their implementation of environmental strategies and policies (ISO, 2010). In this way, they set the stage for an Environmental Management System (EMS) to be employed by the company. ISO (2010) claims that the adoption of an EMS (e.g. ISO 14000 standards) will allow organizations to become aware of the impact their business has on the environment and allow them to improve their performance in a progressive manner. At the same time, this management system provides a systematic approach for establishing environmental goals as well as attaining these goals and later on demonstrating that they are achieved.

The family of ISO 14000 is composed of two main standards that are complemented by a group of supporting standards. The main standards are ISO 14001, which identifies the requirements for an EMS and the ISO 14004 that provides guidelines on the formation, execution, preservation and improvement of an environmental management system. The other standards in the family extend the main ones by providing more specifics on a variety of environmental features including labeling, performance appraisals, life cycle analysis, communications and auditing (ISO, 2010).

It must be noted the EMS concept is not just limited with the ISO 14000 standards. There are other formalized approaches for implementing environmental management systems like Eco-Management and Audit Scheme (EMAS) of the European Commission for EU countries (Casadesus et al., 2008: 1742-1743; Iraldo et al., 2009: 1444). Despite the presence of these alternative methodologies, ISO 14000 family of standards still remains to be the most internationally acknowledged and well-established approach for environmental management (Casadesus et al., 2008: 1743).

Since the inception of ISO 14000 in 1996, there has been a substantial amount of research appearing in the literature. An online search on the SSCI and SCI-expanded indexed journals by using the keyword "ISO 14000" (and its variants like "ISO 14001" and "ISO 14004") revealed that more than 500 research articles were written on the subject in the last fourteen years. A particular focus of these studies is the examination of the implementations of these standards in various sectors across various countries. Examples include many regions from all over the world like Turkey (Turk, 2009a: 713-733; Turk, 2009b: 559-569), Poland (Matuszak-Flejszman, 2009: 411-419), Spain (Bernardo et al., 2009: 742-750), Brazil (de Oliveira and Pinheiro, 2009: 883-885), Japan (Nishitani, 2009: 669-679) and China (Stalley, 2009: 567-590). Clearly these standards and environmental management systems will draw further research attention in the coming days as their recognition escalates and their implementation becomes more widespread.

In addition to this primary concentration of research about the environmental standards, it is possible to find studies that investigate other organizational issues as well. For example, Hansen et al. (2002: 37-56) have explored the potential of environmental innovations in small and medium sized enterprises and concluded that the innovative capability of a SME is directly related with the interaction between the firm's core competencies, its network of relations and the strategic orientation of the company. Another study on SMEs was conducted by van Hemel and Cramer (2002: 439-453). In this study, the authors have investigated the barriers and stimuli for ecodesigns in SMEs. Based on a survey conducted on Dutch SMEs the authors concluded that the internal stimuli in a firm (i.e., opportunity for innovation, expected increase in product quality and potential market opportunities) were more influential than external stimuli (i.e., customer demands, government legislations and industrial sector initiatives) for going green. On the other hand, the most important barriers for ecodesigns were reported to be the perceptions that no clear benefits would be gained, not feeling responsible for the environmental degradation and a conflict of the environmental goals with the other functional requirements of a firm.

1.2. The Research on Environmentally Conscious Design and Manufacturing

Research classified under the first category was particularly related with the process and the organizational issues rather than the outcome of the business itself, namely products and services. On the other hand, the focus of the second branch is solely on the outcome. The research investigated the implications of environmental issues in the design and manufacturing of products and services. The studies also explored ways to reduce the negative effect of the traditional production systems on the environment and tried to come up with innovative ways that will attain sustainable products and services.

On this theme, Florida (1996: 80-105) asked the question of “does lean mean green?” implying the implications of lean manufacturing practices on the environmentally sensitive design and products. The author have conducted a survey on the US manufacturing firms and concluded that lean does not necessarily mean green. However, he added that lean manufacturing provides great opportunities for the implementation of green philosophies. Exploiting these opportunities, current operation management practices not only “can” but “should” give a high priority to sustainability issues (Kleindorfer et al., 2005: 489-490). Kleindorfer et al. (2005: 489-490) asserted that contemporary operation management should consider the triple bottom line constrain (3BL) that is people, profit and planet. The emphasis should be on designing and manufacturing products and services that will successfully satisfy consumer needs without violating the shareholders’ interests and at the same time taking into account their effects on the environment.

1.2.1. The Research Concentrated on the Design Involving a Single Stage in a Product’s Life

From an operations management perspective, this field of research represents, historically, the first approach to environmentally conscious design and manufacturing (Roy, 2000: 289-291). After the basic concepts of green design was established in the 1980s, the preliminary practices in the field were related to the removal of waste from factory grounds or the recycling of products that have reached the end of their useful lives. These practices were called “end-of-pipe” approaches (Florida, 1996: 81-83; Roy, 2000: 289-290), since in most cases a single facility was added to an existing facility to establish the functions of recycling or waste removal. In this way, there was no major change in the design of products. The modifications that occurred were generally in the form of minor revisions conducted at the end-of-life stage of a particular product.

The methodologies for achieving these modifications are generally known as “Design for X” or shortly DfX, with “X” representing the targeted life cycle stage. Some commonly used DfX methodologies are “Design for Disassembly” and “Design for Recycling” (Argument et al., 1998: 64-69). Design for Disassembly required that the products should be easily separated to its components so that these components can be reused, recycled or disposed in a simple and economic way. Design for Recycling is a narrower approach aiming only at the recycling of a whole product or its component parts.

Although these approaches are drawing relatively less attention nowadays, it is still possible to find research that is predominantly focused on only the waste removal or recycling stages in a manufacturing system. For example, Ardente et al. (2003: 101-118) have proposed a model based on a Design for Recycling approach. Their model was aiming to select an alternative with the highest recyclability potential among different alternatives of implementation and was based on the multi-attribute decision making theory. They provided support to their model through a simulated case study. On Design for Recycling research, it is also possible to encounter studies that undertake a full economics perspective. In a general equilibrium model, Eichner and Pethig (2001: 109-134; 2003: 477-499) have integrated the environmental aspects by taking into account the recycling and waste costs and attempted to come up with tax-subsidy schemes to facilitate recycling and efficient disposal of waste generated.

There are examples of application oriented research based on case studies as well. Todd, Brown and Wells (2003: 422-440) provided five case studies on the implementation of waste treatment practices and restoration of pollution. Graedel (2002: 107-115) has focused on material substitution, which is replacing the materials that produce harmful waste or those which are harder to recycle by some less problematic alternatives. He supported his views by providing references to case studies including recycling of car catalytic converters and ammunition.

1.2.2. The Research Concentrated on the Design Involving Whole Life Cycle of a Product

The research categorized under this branch is not focused only on the recycling of products or treatments of their waste. It adopts a broader perspective in the form of designing, manufacturing, utilization and disposal of products that involves every phase of a product's existence. This perspective generally implies a complete redesigning of the product to achieve greater improvements in its environmental impact. In this respect, this approach can be called a systems approach, since it assumes the whole life cycle as a system and makes analysis by considering the totality of the system (Hersh, 1998: 497-505). The most commonly used methodologies are "Life Cycle Assessment"(LCA) and "Design for Environment"(DfE) frameworks. Essentially both of these methodologies are similar in content and application; however, the primary difference between them is that DfE techniques concentrate more on the design stage, while LCA techniques concentrate more on the analysis of a particular product's life cycle (Hersh, 1998: 502-505).

The DfE and LCA frameworks state that the properties and characteristics of the raw materials in terms of waste and reuse, the efficiency and the energy consumption of the manufacturing process, the efficiency of the whole distribution and transportation network, the acceptance and consumption of the product by the end-users and finally the disposal and recycling of the product that has expired its useful life are all critical factors that must be considered in the design of a product. Moreover, Burall (1991: 53-60) suggests that the designers should also consider maintenance, repair and upgrading as stages of the life cycle in an attempt to prolong the useful life of a product so that the recycling and disposal can occur much later in time.

Closely related approaches to LCA are the “life cycle cost” (LCC) or “life cycle cost analysis” (LCCA) techniques. These methods deal with calculation and analysis of total life cycle costs of products to the users and the total life cycle profits to the producers (Hanssen, 1999: 28). The main aim of the LCC/LCCA framework is finding and minimizing the total cost of design/development, production, use and disposal related with a product (Durairaj et al., 2002: 32).

In the literature, it is possible to locate many studies aiming to develop more specialized tools and methods, which take these general frameworks as the basis for their models (e.g. Fullerton and Wu, 1998: 131-148; Chen, 2001: 250-263; Madu et al., 2002: 261-272; Nielsen and Wenzel, 2002: 247-257; Maclean and Lave, 2003: 5445-5452; Senthil et al., 2003: 51-72; Calcott and Walls, 2005: 287-305). There are also studies that provide comparisons among these proposed methods and tools. Hertwich et al. (1997: 24-27) have compared six different methods that are based on DfE and LCA frameworks and concluded that although all the six methods served to achieve the same purposes there were important differences in the values they use for measuring impact, how these values are combined to obtain the final scores as well as the depth of analysis to achieve the final scores. Another comparison was provided by Durairaj et al. (2002: 30-39). They have compared eight different methods that were all based on LCCA. They have highlighted some of the deficiencies of those models and proposed a methodology to develop new methods and tools for an improved LCCA framework.

The ideas behind the life cycle approaches also find applications within the area of industrial facilities and landscapes. This branch of research is usually called as the industrial ecology (Frosch, 1995: 16-37; Grant, 1997: 75-78; Finster et al., 2002: 107-125) and primarily deals with the environmentally efficient design, location and operation of industrial facilities. Frosch (1995: 16-23) states that the traditional industrial system was based on an open system; that is, raw materials are converted in the manufacturing process to the products, which are then used and the left-overs are removed from the system. However, this is not the way a natural ecosystem operates. In a natural ecosystem, the materials and energy forms a closed loop, continuously circulating in the environment. In a similar manner, the new system of industrial ecology should imitate these principles observed in natural ecosystems and apply them to the design and management of industrial systems. Grant (1997: 75-76) suggests that industrial ecology necessitates the minimization of wastes, reduced consumption of energy, reused waste energy, more efficient use of the landscape and conservation of raw materials as best as possible. Based on this notion, several eco-industrial parks are developed around the world and many more are underway (Potts Carr, 1998: 239-257; Oh et al., 2005: 269-284).

The life cycle approaches also have great influences on the residential or commercial architecture and construction applications (e.g. Babcock, 2003: 56-59; Arsan, 2008, Erkaslan, 2009, Rajendran et al., 2009: 1058-1066). The design and construction of buildings are becoming more sensitive to the environment. Architects are encouraged to use whole building designs with waste treatment systems that utilize high performance, environmentally efficient materials and lighting, and heating systems that are more energy efficient.

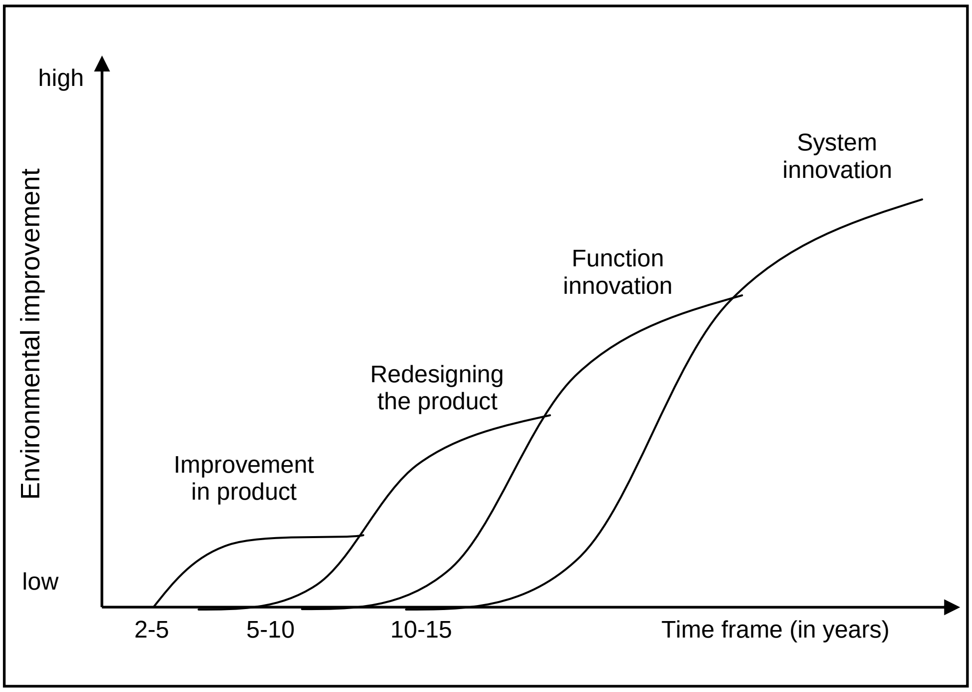
There are other applied research that can be classified under this branch. For example, Meinders and Meuffels (2001: 348-354) talk about the green practices that are utilized in Philips and mention a case study based on "Philips Free Power Radio AE1000" that is completely designed and produced according to LCA principles. Six other case studies that are also analyzable by LCA methodologies were cited by Hanssen (1999: 27-41). These case studies were selected from NEP project (the Nordic Project for Environmentally Sound Product Development) and ranged from offshore coating to sports underwear.

In conclusion, this branch of research has raised considerable attention and found many areas of applicability. However, there is still much work to do here. The most important need for research seems to be on the empirical testing of the proposed life cycle tools and methods. Only after that, more refined models and tools that are highly useful in real life settings can be developed.

1.2.3. The Research Concentrated on the Design of Sustainable Products and Services

As the arguments in previous sections suggest many different concepts and approaches were developed to deal with the environmental issues including DfX techniques, DfE methodologies and LCA approaches. However, there appears to be a need for more innovative solutions and methods to establish higher levels of environmental consciousness and to reach sustainability in a global level. Accordingly, the research classified under this branch addresses these concerns with a focus on the word 'sustainability'. Within this context, sustainability can be described as designing, producing and consuming by considering both the current needs of the public and needs of the future generations. Seeking sustainability is not limited to just products and facilities but includes services and societies as well. In this way, sustainability brings a much broader perspective to the green design while encompassing all the previously mentioned methodologies. Van der Zwan and Bhamra (2003: 898) and Meinders and Meuffels (2001: 350) summarize these concepts with the "road to sustainability" graph which is shown in Figure 2.

Figure 2: The Road to Sustainability Graph



Source: Adapted from van der Zwan and Bhamra, 2003: 898 and Meinders and Meuffels, 2001: 350.

The "improvement in product" curve represents very quick innovations that produce minor changes in the products or represents end-of-pipe approaches. This type of innovations can only bring very few environmental benefits. The "redesigning the product" curve represents innovations that take relatively short time, while providing moderate environmental improvements. The life cycle approaches of LCA and DfE are members of this category. The third innovation category of "function innovation" requires the transition from product oriented approaches to function oriented ones and includes innovations in both the products and services relevant to the functions. This category brings higher environmental benefits in a moderate time frame. The last curve "system innovation" is a representation of the currently foreseen ceiling in global sustainability. It involves major changes in the lifestyles and consumption patterns of the society as well as major revisions to the infrastructure in terms of energy, transportation and material cycles (Hanssen, 1999: 27-28). It provides the highest environmental benefits that require the largest time horizon to become realizable.

The state of the current research is somewhere between the "redesigning the product" and "function innovation" stages. The "function innovation" stage acts as a bridge between the majority of current practices and the ultimate "system innovation". For this reason, the opportunities, limitations and applications of "function innovation" stage has to be explored in an extensive manner to provide the background for the next generation of research. The literature on function innovation usually involves systems of products and services combined together to provide the required function. These systems are known as sustainable product-service systems or just "product-service systems" (shortly "PSS").

The product-service systems research constitutes one of the important topics in this literature and draws a noteworthy attention. A section of UNEP (United Nations Environment Programme) is devoted to these systems (the associated website is http://www.unep.fr/scp/design/pss.htm) and a special issue of Journal of Cleaner Production (Volume 11, Number 8, 2003) was dedicated to the subject. Supportively, many papers have already appeared in the area. This popular and important area of research will be briefly described along with the implications and applications in the next section.

2. SUSTAINABLE PRODUCT-SERVICE SYSTEMS

Sustainable product-service systems are based on the key assumption that what satisfies the costumers is the utility they receive from the products, not necessarily the products themselves. The costumers seek functions not the products to fulfill their needs (Tukker and Tischner, 2006: 1552). For example, people are seeking the function of mobility or transportation and for this they do not need to buy a car. Costumers are in need of the function of cleaning their clothes and they will not buy a washing machine if in another way this function is satisfied (Roy, 2000: 293). Under most circumstances whether owning a product or not will not matter as soon as the functions are delivered to the customers so that their needs are satisfied. Therefore Baines et al. (2007: 1543) state that product-service systems accentuate 'sale of use' instead of 'sale of product'.

Based on this assumption, product-service systems provide innovations in replacing the traditional product oriented industry and consumption with a more function oriented pattern that is more flexible and involving both the aspects of services and products. The characteristics of the traditional product oriented system and the function oriented product-service systems are provided in Table 1.

Table 1: Characteristics of the Traditional Product Oriented System and the Function-Oriented Product-Service Systems

Product oriented system	**Function oriented system**
Customer buys a product to satisfy his/her need.	Customer buys a service from a company to satisfy its need (based on the customer preferences the company determines the best available product and methods)
Customer owns, uses, keeps and maintains the product. The quality of the work done with the product will be dependent on the customer.	Company owns and maintains the product. Company will be responsible from the quality of the work done.
Customer will pay an initial sum to own the product.	Cost to customers will be spread in time.
Use of the product may bring inconvenience in terms of time, effort and energy spent.	Company will face the inconvenience continuously and will seek out the optimization of time, effort and energy spent.
Customer is responsible from the disposal or replacement of the product.	Company is responsible from the disposal and can choose to increase the life of the product or choose to recycle.

Source: Adapted from UNEP, 2002: 4.

The examination of the table reveals that, the function-oriented system has lots of opportunities to go green. The product-service companies will seek out ways to minimize the use of raw materials and energy to increase their profits. They will try to prolong the life of their assets and/or try to recycle and reuse them. Moreover, if the provided service requires transportation and distribution of products, these processes will also be optimized to increase the efficiency so that the distribution takes less time and consumes less fuel. All of these efforts contribute to the environmental sustainability.

Roy (2000: 293-297) talks about different types of sustainable product-service systems. He reports four types. The first type of system is the "result service" which is a system that provides the function to the customers. He gives the example of a system that provides 'clean clothes' rather than washing machines for this case. The second type of product-service systems is called "shared utilization services". These services involve sharing of the products to improve the utilization of those products. The best example for this type is the car sharing and bicycle pooling practices or using the laundries to clean clothes instead of buying washing machines. "Product-life extension services" forms the third category. This system includes maintaining, repairing, recycling and reusing of the products in an attempt to increase their useful lives so that the amount of materials and energy spent in manufacturing new products and the waste generated by disposal will be reduced. The last category consists of the systems that target "demand-side management" which tries to reduce the demand of products rather than increase the supply of them. An example to these types of systems would be providing alternative heat conservation techniques to reduce the demand of heating. Mont (2002: 238-239) also supports these ideas by citing some real life trends in product-service systems. These trends include the sale of the use of products rather than products themselves, the substitutions of traditional products with service machines, the increase in leasing services, the increase in repair services and the change in user attitudes from product orientation to function orientation.

In terms of their benefits, the product-service systems carry the potential to lead to sustainable consumption patterns in the society (Briceno and Stagl, 2006: 1542-1543; Kang and Wimmer, 2008: 1148-1151). These systems are not only advantageous for the environment, but they are also considered as win-win systems where there are gains for every party involved, namely the costumers, companies and the government (Mont, 2002: 239-240; UNEP, 2002: 7-10).

The major benefits of these systems for the *governments* are

- Opportunity to pursue more sustainable policies based on function oriented lifestyles and consumption patterns.
- Reduced concerns on depletion of raw materials and energy consumption.
- Reduced concerns on waste management and recycling.
- New opportunities for employment particularly in the service sector.

The major benefits of these systems for the *companies* are

- Opportunities for diversification in business by including the service component.
- Opportunities for technological innovation and development to satisfy the needs.
- Opportunities to improve the production and distribution efficiency.
- Opportunities to improve the maintenance, repairing, recycling and reuse efficiency.
- Opportunities to build a more environmentally friendly image.
- Improved and longer-term relationships with the customers.
- Opportunities to attract a larger base of customers.

The major benefits of these systems for the *customers* are

- More *economical* solutions for fulfilling their needs.
- More *convenient* solutions for fulfilling their needs.
- More environmentally friendly solutions for fulfilling their needs.
- Lower concerns for storing and maintaining the products.
- Lower concerns for the disposal and replacement of products.
- Higher expectations of total quality.

In order to attain these benefits, some tools and methodologies have been proposed. Van der Zwan and Bhamra (2003: 901-902) have suggested an approach based on function innovation they called “alternative function fulfillment” for designing sustainable product and services. Maxwell and van der Vorst (2003: 884-890) have developed a method called ‘Sustainable Product and Service Development’ (SPSD) and illustrated its application by using ESP (Environmentally Superior Products) initiative in Ireland through two case studies. In a later study, they tested the effectiveness of their methodology in the industry through a larger set of companies, and offered some refinements and improvements (Maxwell et al., 2006: 1470-1477) to the basic technique. A very recent model is developed by Yang et al. (2009: 224-235). Pointing out the scarcity of methodologies to facilitate product-service systems for consumer products, the authors have designed a tool in the form of a computerized management information system that receives product life cycle data and generates a product oriented PSS associated with a particular consumer product.

On a slightly different issue, Cook et al. (2006: 1457-1463) were more concerned with the successful transfer of the product-service system concepts from academic institutions into real-life applications in industry. To facilitate such a transfer, they proposed the 'accessibility, mobility, receptivity (AMR) interactive process' method, and provided a demonstration of it through a case study involving UK manufacturing firms.

Complementing these theory originated research, there are also studies that investigate the properties of practical applications of product-service systems that are available in real life. Manzini and Vezzoli (2003: 851-857) describes some product-service systems that were candidates for an Italian prize on environmentally friendly innovations. A total of four case studies were examined in terms of their capability as product-service systems. Based on their observations on three real-life cases that attempted to create product-service systems for food production, Evans et al. (2007: 4241-4245) conclude that for a PSS to be truly successful, a close collaboration among all the private and public actors working with the production firm is needed. Other real life examples for these systems cover a wide range of applications including a chemical management service (Stoughton and Votta, 2003: 839-849), a telecentre which is a service that provides office space and related facilities such as computer, internet and communications that will be rent for short periods of time (Morelli, 2003: 73-99), and automotive sector based on the practices observed in Ford (Schmidt, 2001: 118-125). The only application oriented study coming from the Turkish industry was conducted by Kelemci-Schneider and Somtürk (2008: 1-18). In this research, the authors discussed the opportunities and hindrances of applying the PSS concept in Turkish Chemical Paint Industry. All these real-life applications are strong portents that sustainable product-service systems have the potential to be a pervasive way of how future product and service are delivered to the consumers and that we will encounter with many more applications in the days to come.

3. DISCUSSION AND DIRECTIONS FOR FUTURE RESEARCH

In this article, I tried to provide a state-of-the-art on the important concept broadly known as the `green design`. Since the research conducted on the topic is quite diverse and diffused in a multitude of disciplines, for an effective summary, I categorized the studies appearing in recent years and presented a classification that organizes them in content wise and progress wise manner. Afterwards, I attempted to provide a brief picture of research contained within each category with an emphasis on the last branch which is related to the aspects of design and production.

Overall, the most prevailing point emerging from this review is that although the research on green design produced a plethora of studies attaining coverage in a wide range of disciplines, there are still many loose ends left untied. Even after all these years of research, there are still no unique and clear prescriptions or roadmaps on how to make the world survive for many generations to come. In this respect, we are still somewhere in the beginning of our journey and there exist many opportunities for future research agendas.

One such opportunity seems to lie in the area of sustainable product-service systems. These systems represent the next stage of research following the complete redesign of products. The work done in this area is just about a decade old, and by all means can be considered to be in its infancy stage. Given the theoretical background and already appearing real life applications, the product-service systems seem to be quite promising for a sustainable world. However, like every system, they are not perfect, and there exist some hindrances that prevent these systems from enjoying a rapid and widespread utilization in practice.

The major barrier to product-service systems is the necessity of a persistent shift in the society from the ownership focused product orientation to service focused function orientation (Roy, 2000: 289-299; Mont, 2002: 238-239; UNEP, 2002: 4-10; Hirschl et al., 2003: 873-881). In this transition, the perceptions of users of product-service systems carry critical importance. So far in their struggle to achieve economically attractive and ecologically friendly solutions, the researchers have largely neglected the social and psychological aspects of product-service systems (Halme et al., 2004: 125,136). In the end, it is the interest and utilization of users that will determine whether a particular product-service system can be deemed successful and attains a widespread acceptance from the society. Supporting this fact, the arguments and examples in the literature clearly show that not all product-service systems can succeed, and even may lead to ‘rebound effects’ creating increased demand for products (UNEP, 2002: 14-15). Clearly, there is urgent need of research on user perceptions and attitudes on these systems to develop more successful and encompassing product-service system methodologies and applications to carry the world to the next stage of system innovation for a `greener` world.

REFERENCES

Ardente, F., G. Beccali, and M. Cellura (2003) "Eco-sustainable Energy and Environmental Strategies in Design for Recycling: The Software "ENDLESS", **Ecological Modelling**, 163, 101-118.

Argument, L., F. Lettice and T. Bhamra (1998) "Environmentally Conscious Design: Matching Industry Requirements with Academic Research", **Design Studies**, 19, 63-80.

Arsan, Z.D. (2008) "Türkiye'de Sürdürülebilir Mimari", **Mimarlık Dergisi**, 340, Available: http://www.mimarlarodasi.org.tr/mimarlikdergisi/index.cfm?sayfa=mimarlikandDergiSayi=290&RecID=1701, accessed on Dec 13th, 2010.

Babcock, R. R., (2003) "Green Design Grows Up: Real world Examples of High-Performance Buildings Cut Costs and Please End-users", **Buildings & Building Interiors**, 56-59.

Baines, T.S. vd., (2007) "State-of-the-art in Product Service Systems", **Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture**, 221(10), 1543-1552.

Ball, J. (2002) "Can ISO 14000 and Eco-labelling Turn the Construction Industry Green?", **Building and Environment**, 37, 421-428.

Baumann, H., F. Boons and A. Bragd, (2002) "Mapping the Green Product Development Field: Engineering, Policy and Business Perspectives", **Journal of Cleaner Production**, 10, 409-425.

Bernardo, M., M. Casadesus, S. Karapetrovic and I. Heras (2009) "How Integrated are Environmental, Quality and other Standardized Management Systems? An Empirical Study", **Journal of Cleaner Production**, 17, 742-750.

Boevers, J. (2008) "Assessing the Utility of Beach Ecolabels for use by Local Management", **Coastal Management**, 36, 524-531.

Briceno, T. and S. Stagl (2006) "The Role of Social Processes for Sustainable Consumption", **Journal of Cleaner Production**, 14, 1541-1551.

Burall, P. (1991) **Green Design**, Great Britain: Bourne Press Ltd.

Calcott, P. and M. Walls (2005) "Waste, Recycling, and ''Design for Environment'': Roles for Markets and Policy Instruments", **Resource and Energy Economics**, 27, 287-305.

Casadesus, M., F. Marimon and I. Heras (2008) "ISO 14001 Diffusion after the Success of the ISO 9001 Model", **Journal of Cleaner Production**, 16, 1741-1754.

Chan, E.S.W. and S.C.K. Wong (2006) "Motivations for ISO 14001 in the Hotel Industry", **Tourism Management**, 27, 481-492.

Chen, C. (2001) "Design for the Environment: A Quality-Based Model for Green Product Development", **Management Science**, 47(2), 250-263.

Ciocci, R. and M. Pecht (2006) "Impact of Environmental Regulations on Green Electronics Manufacture", **Microelectronics International**, 23(2), 45-50.

Cook, M.B., T.A. Bhamra, and M. Lemon (2006) "The Transfer and Application of Product Service Systems: From Academia to UK Manufacturing Firms", **Journal of Cleaner Production**, 14, 1455-1465.

De Oliveira, O.J. and C.R.M.S. Pinheiro (2009) "Best Practices for the Implantation of ISO 14001 Norms: a Study of Change Management in two Industrial Companies in the Midwest Region of the State of Sao Paulo – Brazil", **Journal of Cleaner Production**, 17, 883-885.

De Snoo, G.R. and G.W.J. van de Ven (1999) "Environmental Themes on Ecolabels", **Landscape and Urban Planning**, 46, 179-184.

Durairaj, S.K., S.K. Ong, A.Y.C. Nee, and R.B.H. Tan (2002) "Evaluation of Life Cycle Cost Analysis Methodologies", **Corporate Environmental Strategy**, 9(1), 30-39.

Eichner, T. and R. Pethig (2001) "Product Design and Efficient Management of Recycling and Waste Treatment", **Journal of Environmental Economics and Management**, 41, 109-134.

Eichner, T. and R. Pethig (2003) "Corrective Taxation for Curbing Pollution and Promoting Green Product Design and Recycling", **Environmental and Resource Economics**, 41, 477-500.

Erkaslan, Ö. (2009) "Çevre Duyarlı Tasarım", **Mimarlık Dergisi**, 349, Available: http://www.mimarlarodasi.org.tr/mimarlikdergisi/index.cfm?sayfa=mimarlik&DergiSayi=363&RecID=2187, accessed on Dec 13th, 2010.

Evans, S., P.J. Partidario and J. Lambert (2007) "Industrialization as a Key Element of Sustainable Product-Service Solutions", **International Journal of Production Research**, 45(18-19), 4225-4246.

Finster, M., P. Eagan and D. Hussey (2002) "Linking Industrial Ecology with Business Strategy: Creating Value for Green Product Design", **Journal of Industrial Ecology**, 5(3), 107-125.

Florida, R. (1996) "Lean and Green: The Move to Environmentally Conscious Manufacturing", **California Management Review**, 39(1), 80-105.

Frosch, R.A. (1995) "Industrial Ecology: Adapting Technology for a Sustainable World", **Environment**, 37(10), 16-37.

Fullerton, D. and W. Wu (1998) "Policies for Green Design", **Journal of Environmental Economics and Management**, 36, 131-148.

Glantschnig, W.J. (1994) "Green Design: An Introduction to Issues and Challenges", **IEEE Transactions on Components, Packaging, and Manufacturing Technology-Part A.**, 17(4), 508-513.

Grant, J. (1997) "Planning and designing industrial landscapes for eco-efficiency", **Journal of Cleaner Production**, 5(1-2), 75-78.

Gerbens-Leenes, P.W., H.C. Moll and A. J.M. Schoot Uiterkamp (2003) "Design and Development of a Measuring Method for Environmental Sustainability in Food Production Systems", **Ecological Economics**, 46, 231-248.

Graedel, T.E. (2002) "Material Substitution: a Resource Supply Perspective", **Resources Conservation and Recycling**, 34, 107-115.

Halme, M. C. Jasch and M. Scharp (2004) "Sustainable Home Services? Toward Household Services that Enhance Ecological, Social and Economic Sustainability", **Ecological Economics**, 51, 125-138.

Hansen, O.E., B. Søndergård, and S. Meredith (2002) "Environmental Innovations in Small and Medium Sized Enterprises", **Technology Analysis and Strategic Management**, 14(1), 37-56.

Hanssen, O.J. (1999) "Sustainable Product Systems-Experiences Based on Case Projects in Sustainable Product Development", **Journal of Cleaner Production**, 7, 27-41.

Hersh, M.A. (1998) "A Systems Approach to Green Design, with Illustrations from the Computer Industry", **Systems Research and Behavioral Science,** 15, 497-510.

Hertwich, E.G., W. S. Pease, and C. P. Koshland (1997) "Evaluating the Environmental Impact of Products and Production Processes: A Comparison of Six Methods", **The Science of the Total Environment**, 196, 13-29.

Hirschl, B., W. Konrad and G. Scholl (2003) "New Concepts in Product use for Sustainable Consumption", **Journal of Cleaner Production**, 11, 873-881.

Iraldo, F., F. Testa and M. Frey (2009) "Is an Environmental Management System able to Influence Environmental and Competitive Performance? The Case of the eco-management and audit scheme (EMAS) in the European Union", **Journal of Cleaner Production**, 17, 1444-1452.

ISO, International Organization for Standardization (2010) **ISO 14000 Essentials**, Available: http://www.iso.org/iso/iso_catalogue/management_standards/iso_9000_iso_14000/iso_14000_essentials.htm, accessed on Dec 13th, 2010.

Kang, M.J. and R. Wimmer (2008) "Product Service Systems as Systemic Cures for Obese Consumption and Production", **Journal of Cleaner Production**, 16, 1146-1152.

Kelemci Schneider, G. and S.M. Somtürk (2008) "Endüstriyel Ürünlerde Sürdürülebilir Pazarlama Yaklaşımına Bir Araç Olarak 'Ürün-Servis-Sistemleri (Product-Service-System)'-Türk Boya Sanayisinde Bir Uygulama", **2008 Muhan Soysal İşletmecilik Konferansı**, ODTÜ Kuzey Kıbrıs Kampüsü, 3-6 Eylül 2008.

Kleindorfer, P.R, K. Singhal and L.N. Van Wassenhove (2005) "Sustainable Operations Management", **Production and Operations Management**, 14(4), 482-492.

Li, C., X. Zhang, S. Zhang and K. Suzuki (2009) "Environmentally Conscious Design of Chemical Processes and Products: Multi-Optimization Method", **Chemical Engineering Research and Design**, 87, 233-243.

Maclean, H.L. and L.B. Lave (2003) "Life Cycle Assessment of Automobile/Fuel Options", **Environmental Science and Technology**, 37(23), 5445-5452.

Madu, C.N., C. Kuei and I.E. Madu, (2002) "A Hierarchic Metric Approach for Integration of Green Issues in Manufacturing: A Paper Recycling Application", **Journal of Environmental Management**, 64, 261-272.

Manzini, E. and C. Vezzoli (2003) "A Strategic Design Approach to Develop Sustainable product Service Systems: Examples Taken from the 'Environmentally Friendly Innovation' Italian prize", **Journal of Cleaner Production**, 11, 851-857.

Marukawa, K. and K.L. Edwards (2001) "Development of Iron and Steel into Eco-material", **Materials and Design**, 22, 133-136.

Matuszak-Flejszman, A. (2009) "Benefits of Environmental Management System in Polish Companies Compliant with ISO 14001", **Polish Journal of Environmental Studies**, 18(3), 411-419.

Maxwell, D., W. Sheate and R. Van der Vorst (2006) "Functional and Systems Aspects of the Sustainable Product and Service Development Approach for Industry", **Journal of Cleaner Production**, 14, 1466-1479.

Maxwell, D. and R. Van der Vorst (2003) "Developing Sustainable Products and Services", **Journal of Cleaner Production,** 11, 883-895.

Meinders, H. and M. Meuffels (2001) "Product Chain Responsibility–An Industry Perspective", **Corporate Environmental Strategy**, 8(4), 348-354.

Mont, O.K. (2002) "Clarifying the Concept of Product-Service System", **Journal of Cleaner Production**, 10, 237-245.

Morelli, N. (2003) "Product-Service Systems a Perspective Shift for Designers: A Case Study the Design of a Telecentre", **Design Studies**, 24, 73-99.

Nie, L., M. Pecht and R. Ciocci (2007) "Regulations and Market Trends in Lead Free and Halogen-Free Electronics", **Circuit World**, 33(2), 4-9.

Nielsen, P. H. and H. Wenzel (2002) "Integration of Environmental Aspects in Product Development: A Stepwise Procedure Based on Quantitative Life Cycle Assessment", **Journal of Cleaner Production**, 10, 247-257.

Nimon, W. and J. Beghin (1999) "Ecolabels and International Trade in the Textile and Apparel Market", **American Journal of Agricultural Econonomics**, 81(5), 1078-1083.

Nishitani, K. (2009) "An Empirical Study of the Initial Adoption of ISO 14001 in Japanese Manufacturing Firms", **Ecological Economics**, 68, 669-679.

Oh, D., K. Kim and S. Jeotg (2005) "Eco-Industrial Park Design: A Daedeok Technovalley Case Study", **Habitat International**, 29, 269-284.

Pelletier, N. and P. Tyedmers (2008) "Life Cycle Considerations for ımproving Sustainability Assessments in Seafood Awareness Campaigns", **Environmental Management**, 42(5), 918-931.

Potts Carr, A.J. (1998) "Choctaw Eco-Industrial Park: an Ecological Approach to Industrial land-use Planning and Design", **Landscape and Urban Planning**, 42, 239-257.

Rajendran, S., J.A. Gambetese and M.G. Behm (2009) "Impact of Green Building Design and Construction on Worker Safety and Health", **Journal of Construction Engineering and Management**, 135(10), 1058-1066.

Reed, B., (2007) "Shifting from 'Sustainability' to Regeneration", **Building Research and Information**, 35(6), 674-680.

Reith, C.C. and M.J. Guidry (2003) "Eco-efficiency Analysis of an Agricultural Research Complex", **Journal of Environmental Management**, 68, 219-229.

Roy, R. (2000) "Sustainable Product-Service Systems", **Futures**, 32, 289-299.

Sasidharan, V., E. Sirakaya and D. Kerstetter (2002) "Developing Countries and Tourism Ecolabels", **Tourism Management**, 23, 161-174.

Schmidt, W.P. (2001) "Strategies for Environmentally Sustainable Products and Services", **Corporate Environmental Strategy**, 8(2), 118-125.

Senthil, K.D., S.K. Ong, A.Y.C. Nee and R.B.H. Tan (2003) "A Proposed Tool to Integrate Environmental and Economical Assessments of Products", **Environmental Impact Assessment Review**, 23, 51-72.

Stalley, P. (2009) "Can trade green China? Participation in the Global Economy and the Environmental Performance of Chinese firms", **Journal of Contemporary China**, 18(61), 567-590.

Stoughton, M. and T. Votta (2003) "Implementing Service-Based Chemical Procurement: Lessons and Results", **Journal of Cleaner Production**, 11, 839-849.

Todd, J., E.J.G. Brown and E. Wells (2003) "Ecological Design Applied", **Ecological Engineering**, 20, 421-440.

Tukker, A. and U. Tischner (2006) "Product-Services as a Research Field: Past, Present and Future. Reflections from a Decade of Research", **Journal of Cleaner Production**, 14, 1552-1556.

Turk, A.M. (2009a) "ISO 14000 Environmental Management System in Construction: an Examination of its Application in Turkey", **Total Quality Management and Business Excellence**, 20(7), 713-733.

Turk, A.M. (2009b) "The Benefits Associated with ISO 14001 Certification for Construction firms: Turkish Case", **Journal of Cleaner Production**, 17, 559-569.

UNEP-United Nations Environment Programme (2002) "Product-Service Systems and Sustainability: Opportunities for Sustainable Solutions", Available online: http://www.unep.fr/scp/design/pdf/pss-imp-7.pdf, Dec 13th, 2010.

Van Hemel, C. and J. Cramer (2002) "Barriers and Simuli for Ecodesign in SMEs", **Journal of Cleaner Production**, 10, 439-453.

Van der Zwan, F. and T. Bhamra (2003) "Alternative Function Fulfilment: Incorporating Environmental Considerations into Increased Design Space", **Journal of Cleaner Production**, 11, 879-903.

Yang, X., P. Moore, J-S. Pu, C-B. Wong (2009) "A Practical Methodology for Realizing Product Service Systems for Consumer Products", **Computers and Industrial Engineering**, 56, 224-235.