Proceedings of the 1st CIRP Industrial Product-Service Systems (IPS2) Conference, Cranfield University, 1-2 April 2009, pp273

Remanufacturing on a Framework for Integrated Technology and Product-System Lifecycle Management (ITPSLM)

A. Guelere Filho, D.C.A. Pigosso, A.R. Ometto, H. Rozenfeld
[1]University of São Paulo, São Carlos School of Engineering, São Carlos, Brazil
agf@sc.usp.br

Abstract
In PSS context the product lifecycle needs to be managed in a holistic and structured way by using product life-cycle management (PLM) approach. The remanufacturing is an important strategy in this process, since the parts of a product that is being taken back at the end of its service can be remanufactured and new products send back to the market, fulfilling the needed functions. This paper aims to present a framework for ITPSLM composed by three business process (innovation management, technology development, product-service system development) and two support process (configuration management and business process management) and its relation to remanufacturing.

Keywords:
Remanufacturing; Product-Service Systems; Eco-Innovation; Product Life-Cycle Management

1 INTRODUCTION

The traditional approach to environmental management has evolved from pollution control, the end-of-pipe approach, to preventive or cleaner production approaches. The latter is defined as the continuous redesign of industrial process and products to prevent pollution and waste generation at their source and minimize risks to humans and the environment. This approach was applied initially to industrial processes (hence cleaner technologies) and then, to be more inclusive, to the industrial products themselves (hence cleaner products). Recently, it has become clear that such interventions have to be more radical than just the re-designing of existing products in order to catalyze a transition towards a sustainable society.

Long-term economic growth in combination with a reduced pressure on the environment asks for changes in our production and consumption systems and for commitment of all actors in society, since consumption and production of products throughout its lifecycle is at the origin of most pollution and resources depletion that our society causes.

Economic growth means increasing the perceived value created in society, as expressed in financial terms. It is linked to perceived value creation and not necessarily to material or product streams circulating in the economy. High-perceived value would be achieved by combining an optimal mix of products and services. Furthermore, the image of the product, service and their provider can have a major influence. This results into a value increase of all products in circulation.

On average services are to be preferred over products as a means to perceived value creation. The combination of products and services can exceed the traditional functionality of products, in terms of quality and cost performance.

The following two items presents the literature review carried out in Product-Service Systems (PSS), Product Life-Cycle Management (PLM) and Remanufacturing. In sequence, it is presented our proposal of a framework for Product Life-Cycle Management (PLM) in the Context of Product-Service Systems (PSS) and with focus on remanufacturing.

2 PRODUCT-SERVICE SYSTEMS (PSS)

The Product-Service System (PSS) concept is a possible and promising business strategy potentially capable of helping achieve the leap, which is needed to move to a more sustainable society. PSS can be seen as strategic innovations which companies may choose in order to separate resource consumption from its traditional link to profit and standard of living improvements; to find new profit centers, to compete and generate value and social quality while decreasing (directly or indirectly) total resource consumption.

A Product-Service system is a marketable set of products and services, jointly capable of fulfilling a client's need [1]. It is the result of an innovation strategy, shifting the business focus from designing and selling physical products only, to selling a system of products and services which are jointly capable of fulfilling specific client demands [2]. It is also a result of rethinking of the product value chain and ways of delivering utility to customers that will have a smaller environmental impact than separate products and services outside the system [3].

According to [4], a PSS is a system of products, services, networks of actors and supporting infrastructure that continuously strives to be competitive, satisfy customer needs and have a lower environmental impact than traditional business models.

PSS can prove beneficial to the environment in combination to creating (new) business. Key-factors of success are similar in many cases, e.g.:

- Creating value for clients, by adding quality and comfort.
- Customizing offers or the delivery of the offer to clients.
- Creating new functions or making smart or unique combinations of functions.

- Decreasing the threshold of a large initial or total investment sum by sharing, leasing, and hiring.
- Decreasing environmental load. Often this will bring additional and perceived Eco-benefits.
- Increase the quality of the contacts with clients.

The generic eco drivers for the adoption of PSS are [2]:

- Image improvement.
- Practicing producer's responsibility.
- Covenants with authorities.
- Health and safety management.
- Environmental costs reduction.
- Legislation.
- Published product tests.
- Non Governmental Organizations and societal pressure.
- Green purchasing by authorities or consumers.

The successful application of a product-service system requires that manufacturers and service providers extend their involvement and responsibility from products to phases in the life cycle (figure 1), that are usually outside the traditional buyer-seller relationship, such as take back, recovery of products and materials, reuse and refurbishment and remanufacturing [3].

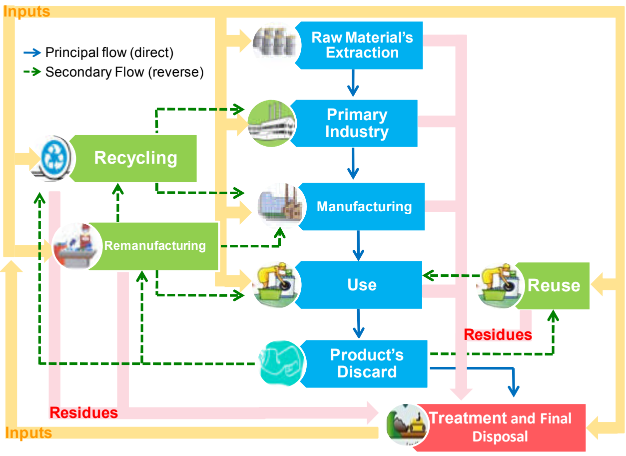

Figure 1: Material Life-Cycle of products.

Producers are playing the role of the coordinating actor in the product chain. Usual responsibilities for products are extended through an increased or deepened responsibility for service, including the responsibility for educating customers and increasing their awareness about efficient product use and for proper organization of the take back arrangements and systems for reuse, remanufacturing and recycling.

Compared to Ecodesign cases, the transition towards PSS will often imply an important process of change for the company towards new thinking on how the company should create value, produce, distribute and approach her clients.

3 PRODUCT LIFE-CYCLE MANAGEMENT (PLM)

Product lifecycle management (PLM) can be defined as a business approach for managing a company's product throughout its life cycle.

The PLM is a key element for companies in creating sustainable value and a competitiveness factor in a market where customers and consumers are interested in the environmental impacts of the products they consume. The legislation is another important factor in this scenario.

- The sustainable value creation includes the product, process, marketing or organization innovation. It embraces the following aspects:
- Increase of the environmental, social and economical performance of an existing product.
- Improvements of products development process.
- Assessment of environmental impacts of products/manufacturing processes in order to minimize its environmental burden.
- Definition of a sustainable supply chain (by the definition of new partners, governance rules, adopted technologies, etc.).

The integrated product life-cycle management perspective is influencing the way organizations plan its business, take strategic decisions, develop products and manufacturing process, manage operations, deal with suppliers and consumers, and plan the end-of-life of its products [5].

A short definition for Product Lifecycle Management states that PLM is a concept for the integrated management of product-related information throughout the entire product lifecycle [6]. This concept is rather broad, but it is in accordance with the CIMDATA [7]: 'PLM is a strategic business approach that applies a consistent set of business solutions in support of the collaborative creation, management, dissemination, and use of product definition information across the extended enterprise from concept to end of life—integrating people, processes, business systems, and information'.

Stark [8] in his book states that PLM represents an approach for effectively managing a company's product throughout its life cycle. He presents an extensive list of needs, justifications, strategies and implementation activities for PLM. Indeed, he emphasizes Product Data Management (PDM) when discussing software. One can come to the understanding that PDM is the heart of PLM, which might be true if the PLM solutions available on the market are analyzed. Nevertheless, project management functionalities are also presented in most existing PLM applications.

4 REMANUFACTURING

Remanufacturing is an end-of-life strategy that reduces the use of raw materials and energy necessary to manufacture new products. Economically, remanufacture is an interesting strategy due to preserving the product's value added during the design and manufacturing processes. As for the environment, the importance of remanufacture lies on extending the product's lifetime, by diverting them into a second life, given that if the products last longer through remanufacturing, less material can be used to meet customer needs [9].

The remanufacture process can be defined as a product recovery strategy focused product restoration and reconditioning of its parts, in order to rebuild it according to its original design. Remanufacture is an effective manner to maintain products in a closed-loop and to guarantee products end-of-life proper management. Remanufacturing helps reducing environmental and economical costs of manufacturing and final disposal costs of products and components [10, 11].

Remanufacturing as an industrial process includes several stages, among them product disassembly, cleaning and identification of parts, parts recovery, testing and product reassembly [10, 11, 12]. Kerr et al. [13] considers remanufacturing the most efficient way to maintain products in a closed loop. Through remanufacturing, products can be restored to a like new condition, with the same quality and function as new products. Thus, remanufacturing of end-of-life products and components reduces environmental and economical costs both in new product manufacturing as at its final disposal.

According to Kerr et al. [13], sustainable production and consumption will only be possible with closed systems. With remanufacturing, a much smaller fraction of the end-of-life resources needs to be recovered through recycling. In addition, intelligent remanufacturing systems provide the opportunity for product upgrades, thereby extending product life and incorporating less environmentally harmful technology.

There are several Ecodesign' methods and tools that focus on end-of-life alternatives, such as remanufacturing, and can be successfully applied in order to obtain more sustainable products. The end-of-life ecodesign methods focused on closing the loop of materials generally include more than one end-of-life strategy. Since a product complexity varies substantially, some components, systems or sub-systems are keener to be recycled, reused or remanufactured than others. The proper end-of-life management system must be able to deal with these characteristics of products parts and adjust the disassembly and parts separation processes to obtain higher profits and better environmental performance and results, optimizing the closure of materials loop.

Six examples of Ecodesign methods and tools oriented to the end-of-life of products are listed below:

<u>Environmental Design Industrial Template (EDIT)</u>: This software acknowledges that economics and product design are the factors establishing the end-of-life of products. The software allows the user to analyze the effects of product's design at its end-of-life. The tools concept is the generation of a product disassembly sequence that optimizes profit generation in a way that end-of-life treatments can be evaluated. This tool allows the designer to define how and with which material the product will be made, choose parts and processes considering some environmental and economic information, access and modify the available data base, and simulate end-of-life results. The user must supply information on materials (weight, toxicity, disposal costs, and information on recycling – material recycling cost and energy used in the process). If parts can be reused or remanufactured, user must inform its costs as well as retail prices. Thus, given the products design, EDIT is able to simulate an optimum disassembly sequence with larger economic value. As a result, the designer knows to which extend the product can be reused, remanufactured, recycled or disposed, plus time and energy spent on the disassembly process [14].

<u>Environmental Design Support Tool (EDST):</u> Evaluates products design on terms of its environmental sustainability, i.e. material selection, recyclability and disassembly analysis. According to the writers, disassembly is the first step in evaluating a product's environmental performance by this tool, and it provides the time needed on disassembly, number of distinct components and other information. The tool generates an index number to help evaluating the disassembly process (larger numbers imply more difficult disassembly). Material evaluation is made through and index composed by weight of material, total amount of different material used and total amount of dangerous and recyclable materials used. This index is obtained through a questionnaire and its guidelines. Recyclability evaluation is focused on residue management and pollution control. Material end-of-life alternatives are reuse, remanufacture, recycling, incineration and final disposal, according to the kind of material used [15].

<u>Green Design Advisor</u>: evaluates products through eight metrics: number of materials, mass, amount of recycled material, toxicity, energy use, disassembly time and end-of-life disassembly cost. The evaluation is made in two steps: definition of an appropriate data model that includes all relevant data in determining products environmental impact, and environmental point's calculus. Thus, the method can identify the weaknesses of the product and indicates the direction for improvement [16].

<u>Method to Assess the Adaptability of Products (MAAP):</u> the main purpose of this method is to evaluate the product's conformity at assembly, maintenance, repair, upgrade and remanufacture processes, as locating potential design improvement areas. Conformity is represented by metrics (adaptation). The closer the value is to one, better the design adaptation, and the closer to zero, the worst it is. Methods clearness is guaranteed by submetrics (remanufacturing, maintenance, repair and upgrading), which establish together the adaptation metric, as well as parts, connectors and space. The sub-metrics are divided in subcriteria: parts (components and removal direction), connectors (number of different components in each group, number of different components, number of connectors and tools), space (visibility, reach, identification and direction to disassembly), remanufacture (disassembly maintenance, assembly and architecture structure), repair (disassembly, assembly and architecture structure repair) and upgrade (functional and interface decoupling). The evaluation is made through the ratio between the ideal and the real values of a specific parameter. Based on the metrics result, the tool provides guidelines to product improvement in terms of its adaptation [17].

<u>Product Life Cycle Planning (LCP)</u>: this tool considers detailed environmental requirement through life cycle perspective, and the environmental aspect is integrated to quality and cost aspects at initial design phases. The study focus on the following life cycle options: "product upgrade", "product maintenance", "lifetime extension", "product or component reuse", and "material recycling". At the first stage, a medium or long term production plan and a product plan are established according to business requirements and products lifetime. At the next stage, product specifications and its life cycle are established. The conciliation between costumer and environmental requirements (in accordance with the company's strategy) lead to an adjustment of values for quality and environmental characteristics. LCP is supported by a tool software, the LCPlanner, based on an Microsoft Excel macro. LCPlanner automatically produces several matrix and analysis graphics using entry data supplied by the designer and data from LCA and QFD databases [18].

There are several Ecodesign tools and methods available aiming at end-of-life treatment and alternatives. In order to put it to practice, Ecodesign' methods and tools must be integrated to the initial phases of product development processes in a systematic way. Remanufacturing may become more feasible on the same measure as these Ecodesign tools and methods are made available in a systematic way to designers.

5 INTEGRATED TECHNOLOGY AND PRODUCT-SYSTEM LIFECYCLE MANAGEMENT (ITPSLM) FRAMEWORK

Some proposals of a framework for PLM in the context of PSS already exist, as the Braunschweig Framework of Total Life Cycle Management [19], a systemic and life-cycle oriented framework for a life cycle phase comprehensive point of view on products and the corresponding processes. In the same way, Aurich et al [20] presented in its paper a novel concept for PSS-LCM that considers customer-oriented PSS planning, integrated PSS development, knowledge based PSS control and life cycle-oriented process management. Similar framework approaches has also been presented by other authors.

This paper presents a framework for ITPSLM (Integrated Technology and Product-System Lifecycle Management – figure 2) composed by three business process (Innovation Management, Technology Development and Product-Service System Development) and two support process (Configuration Management – ECM and Business Process Management - BPM). A business process (BP) represents a collection of activities that produces a result (product or service) for a specific group of customers. This definition does not equate to generally defining that a process simply transforms inputs in outputs. A BP aggregates many activities that are normally spread out in different organizational entities (e.g., departments or divisions).

Activities of same nature can also be grouped in knowledge areas known as process areas, such as project management, requirement management, cost management and so on.

The framework presented on figure 2 is divided in three macro-phases that embrace all the lifecycle of a product or product-service system: pre-development, development and post-development.

Innovation Management embraces Innovation Strategic Planning and other innovation management activities (listed on figure 2). The portfolio management, that is present on the gates, can be highlighted.

The Innovation Strategic Planning begins with the corporation innovation strategic planning, where the market, technology, products and services trends prospection is done considering a horizon of some years, depending on the company sector. This planning can be integrated to enterprise or business units strategic planning. The strategic view of this BP is also explored on technology and product development projects, by the application of portfolio planning techniques, for example.

On the context of Technology Development, the analysis of technology, current product-services and new ideas take part. The prioritized projects are the input for two development funnels: technology and product-service (the two BP of ITPSLM). It is important to address, however, that there are differences between these two funnels. The technologies must be available and established to be used on the product development process, after the conceptual design.

The Product-Service System Development is a new concept of New Product Development (NPD) that considers the context of product-service systems. The Product-Service System Development has a broader scope, since the product continues being designed on the “traditional” way. The associated services represent additional activities and new requirements to be considered;

According to [21] new product development (NPD, also frequently referred to just as product development) is ‘The overall process of strategy, organization, concept generation, product and marketing plan creation and evaluation, and commercialization of a new product’. Clark & Fujimoto [22] states that ‘Product development process is the resulting process when market information is transformed into information and necessary sources to manufacture a product with the aim of commercializing it’. For Pugh [23] ‘Product development process is the necessary systematic activity from the identification of the market/customer needs until the product sale, an activity that includes product, processes, people and organization’.

It is not a new notion that developing products has become one of the key processes for competitiveness in manufacturing. A structured and systematized NPD leads to shorter time-to-market, project repeatability, lean development, and knowledge reuse. NPD systematization provides a standard for project management, also known as a reference model. It defines a common language for all stakeholders involved with NPD and represents a body of knowledge.

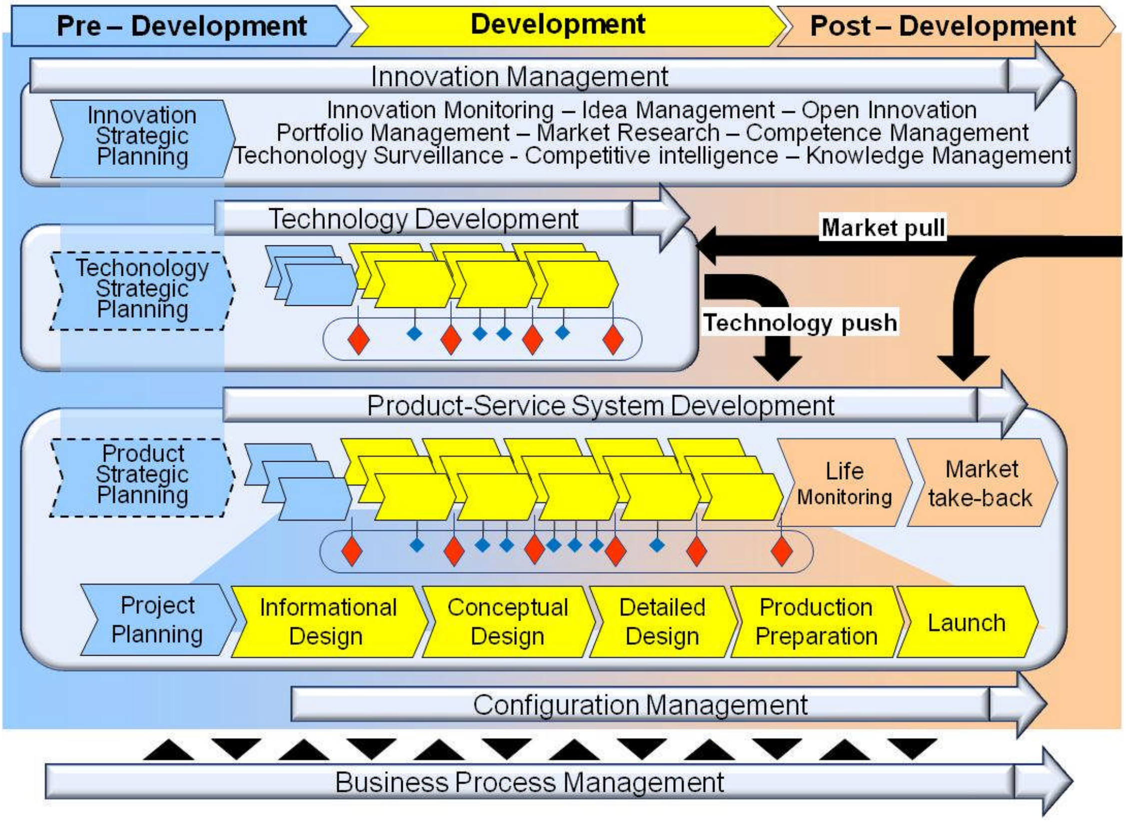

Figure 2: Business Process of Product Life-Cycle Management (PLM)

One of the well-known factors of the NPD is that the degree of uncertainty in the beginning of the process is very high, decreasing over the time. The decisions in the beginning of the development cycle are responsible for 70% of the cost of the final product [24]. Regarding the product related environmental impacts, considering environmental requirements at the beginning of the product development phase can reduce environment impacts by an estimated 70% [25]. Hence, taking environmental aspects into consideration during the NPD phase plays an essential role in reducing product lifecycle-related environmental impacts. It is important to notice that the NPD is the business process where lies the opportunities for innovation in function fulfillment.

The Product-Service System Development also emphasizes the need of a constant and iterative Life Cycle Assessment (LCA) in order to define the requirements and incorporate the sustainable aspects into the PSS;

The two final phases (Life Monitoring and Market Take-Back) are responsible for closing the loop of materials on the product-service lifecycle, a primordial condition to reduce the environmental impact of products. All the previous phases and business process must consider reuse, remanufacturing and recycling as strategies for the products' end-of-life. Reuse is the process of collecting used materials, products, or components from the field, and distributing or selling them as used. Thus, although the ultimate value of the product is also reduced from its original value, no additional processing is required. The process of remanufacturing consists of collecting a used product or component from the field, assessing its condition, and replacing worn, broken, or obsolete parts with new or refurbished parts. In this case, the identity and functionality of the original product is retained. The resulting (remanufactured) product is then inspected and tested, with the goal of meeting or exceeding the quality standards of brand new products. Recycling is the process of collecting used products, components, and/or materials from the field, disassembling them (when necessary), separating them into categories of like materials (e.g. specific plastic types, glass, etc.), and processing into recycled products, components, and/or materials. In this case, the identity and functionality of the original materials are lost. The success of recycling depends on: (1) whether or not there is a market for the recycled materials; and (2) the quality of the recycled materials (since most recycling processes actually reduce the value of the material from its original value, as the material itself has degraded) [26]. Clearly, the choice of which practice is best for an organization will depend on the organization and product characteristics [27].

To successfully implement remanufacturable products, they should have been designed for this purpose previously. Thus, the initial phases of the product-service system development process must consider the aspects of disassembly opportunities, facilities and reverse logistics. Some of the desirable characteristics for remanufacturable products are easy disassembling, easy cleaning, wear resistant, easy to reassemble and valuable when remanufactured.

The Configuration Management (ECM) is related to engineering changes across the whole product life cycle. ECM support process is responsible for manage all the information related to a product. Two distinct terms can be defined in the configuration management: the Configuration Item (CI), that is the collection of all objects that form a product or part of it, and the Configuration Document (CD), that are all the information that characterize the CIs. The configuration management manages the CIs through the management of CDs and CIs meta-data. The configuration management organize and control, in a uniform and systematic way, the descriptions envolving its identification, control and audit.

Business Process Management (BPM) is a field of knowledge at the intersection between management and information technology, encompassing methods, techniques and tools to design, enact, control, and analyze operational business processes involving humans, organizations, applications, documents and other sources of information [28]. BPM deals with the continuous improvements of the entire PLM. It is a structured and systematic approach to analyze, improve, control and manage process aiming to improve the quality of products and services.

Hence, in light of the PSS concept, BPM will be responsible for the shifting from NPD to IPSLM.

6 SUMMARY

Sustainability demands the balance between economical, social and environmental aspects. Most part of the existing environment impacts is product-related. Thus, a significant decrease in product-related environmental impacts is prerequisite to sustainability. The PSS emerges as a promising approach for a more sustainable society, since it makes possible, between other things, the remanufacturing as an end-of-life strategy.

The concept of Product Service System implies a shift in business thinking from selling products to providing service solutions to customer needs. Therefore, the reuse, remanufacturing and recycling of products become more feasible and can be implemented more easily. The introduction of new ownership patterns, such as leasing focused on extending the products lifetime, increases manufacturers interest in designing for durability and enabling the reuse and remanufacturing of products and cores prior to recycling.

The PLM framework in the context of PSS proposed in this paper is unprecedented since it:

- Links all the business process throughout the product life-cycle.
- Includes the conceptual and methodological framework of ecodesign.
- Understands the life-cycle of a product from the raw material extraction to the products' end-of-life.
- Integrates sustainability into the business view in order to aggregate value to the product.
- Includes the product monitoring and take-back, a non-modeled business process, aiming to close the loop of materials in a cycle economy.

The grounding of a strategy for integrating environmental issues into the Product Life-cycle Management process must consider the products complexity and diversity and the fast evolution of knowledge on products and services design. It is important to notice, however, that no environmental improvement will be achieved unless new products are competitive and can fully replace low environmental performance products. Thus, product's functionality, performance, aesthetics, quality and cost must be compatible with environmental requirements.

7 ACKNOWLEDGMENTS

The authors would like to acknowledge to the financial and infrastructure support of Institute Factory of Millenium (IFM), Nucleous of Advanced Manufacturing (NUMA) and FAPESP.

8 REFERENCES

[1] Goedkoop, M.J., van Halen, C.J.G., te Riele, H.R.M., Rommens, P.J.M., 1999, Product Service systems Ecological and Economic Basics.

[2] UNEP, Product Service Systems and Sustainability: Opportunities for Sustainable Sollution. France

[3] Mont, O., 2000, Product-Service Systems, The International Institute of Industrial Environmental Economics, Stockholm, Sweden.

[4] Mont, O., 2004, Product-Service Systems: Panacea or myth?, The International Institute for Industrial Environmental Economis, Lund: Lund University, pp. 146.

[5] Rowledge L.R., Knowledge Management for Sustainable Value Creation, EKOS International.

[6] Saaksvuori, A., Immonen, A., 2004, Product lifecycle management, Springer, Berlin.

[7] CIMdata, 2002, Product Lifecycle Management: Empowering the Future of Business, www.cimdata.com.

[8] Stark, J., 2005, Product lifecycle management: 21st century paradigm for product realization, Springer, London.

[9] Zwolinski, P.; Lopez-Ontiveros, M.A.; Brissaud, D., 2006, Integrated design of remanufacturable products based on product profiles. Journal of Cleaner Production vol. 14 1333-1345.

[10] White, C.D.; Masanet, E.; Rosen, C.M.; Beckman, S.L., 2003, Product recovery with some byte: an overview of management challenges and environmental consequences in reverse manufacturing for the computer industry. Journal of Cleaner Production 11, 445-458.

[11] Kerr, W.; Ryan, C., 2003, Eco-efficiency gains from remanufacturing: A case study of photocopier remanufacturing at Fuji Xerox Australia. Journal of Cleaner Production 9, 75–81.

[12] Sundin, E.; Bras, B., 2005, Making functional sales environmentally and economically beneficial through product remanufacturing. In: Journal of Cleaner Production 13, 913-925.

[13] Kerr W, Ryan C., 2003, Eco-efficiency gains from remanufacturing: A case study of photocopier remanufacturing at Fuji Xerox Australia. Journal of Cleaner Production, 9: 75–81

[14] Spicer, A.; Wang, M, 1997, Environmental Design Industrial Template (EDIT) a software tool for analysis of product retirement. In Journal of Cleaner Production.

[15] Yu, S. Y.; Zhang, H-C.; Ertas, A., 1999, Environmental Conscious Design an Introduction to EDST. In Journal of Integrated Design and Process Science.

[16] Sun, J.; Han, B.; Ekwaro-Osire, S.; Zhang, H-C., 2003, Design for Environment: Methodologies, Tools and Implementation. In: Journal of Integrated Design and Process Science.

[17] Willems, B.; Seliger, G.; Duflou, J.; Basdere, B., 2003, Contribution to Design for Adaptation: Method to Assess the Adaptability of Products (MAAP) In: Proceedings of EmDesIgnW: Third International Symposium on Environmentally Conscious Design and Inverse.

[18] KOBAYASHI, H., 2005, Strategic evolution of eco-products: a product life cycle planning methodology. In Design.

[19] Herrmann, C., Bergmann, L., Thiede S., Halubek, P., 2007. Total Life Cycle Management – An Integrated Approach Towards Sustainability. 3rd International Conference on Life Cycle Management. University of Zurich at Irchel, Zurich.

[20] Aurich, J. C.; Schweitzer, E.; Fuchs, C.: Life Cycle Management of Industrial Product-Service Systems. In: Takata, S.; Umeda, Y. (Hrsg.): Advances in Life Cycle Engineering for Sustainable Manufacturing Businesses, London: Springer, 2007, 171-176.

[21] PDMA Glossary for New Product Development. Avaiable at:

<http://www.pdma.org/library/glossary.html>. Accessed on: Feb. 15th 2007.

[22] Clark, K.B., Fujimoto, T., 2001, Product development performance: strategy, organization and management in the world auto industry, Harvard Business School Press.

[23] Pugh, S., 1990, Total design: integrated methods for successful product engineering, Addison Wesley.

[24] Boothroyd, P., Dewhurst, W., 1994, Product Design and Manufacture for Assembly. Marcel Dekker.

[25] Graedel, E., Allenby, R., 1995, Industrial ecology, Prentice Hall, New Jersey.

[26] Beamon, B.M., 1999, Designing the Green Supply Chain; Logistics Information Management.

[27] Sarkis, J., 2003. A strategic decision framework for green supply chain management, Journal of Cleaner Production.

[28] Van der Aalst, W.M.P., ter Hofstede, A.H.M., Weske, M., 2003, Business Process Management: A Survey, Business Process Management, Proceedings of the First International Conference, Springer Verlag.