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PRODUCT AND PROCESS DESIGN FOR EFFECTIVE REMANUFACTURING TOWARDS A NEW SUSTAINABLE PROSPECT – A REVIEW

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Abstract - *In the Asia, and particularly in the India, recycling has become familiar in public and private arenas as a direct result of continued legislative pressures and public awareness efforts. However, recycling remains limited to simple items such as drinks containers, plastic materials, steel products and paper goods, in part because recycling a more complex product, like a vehicle, the initial manufacture will suffer as loss which is aroung 95% of added value. Remanufacturing, on the other hand, is the ultimate form of recycling. The raw material content can be preserved by remanufacturing by keeping added value as it is. This sectorial analysis aims to build on this current thinking and examine the scope of the industry and its impact on the Asian economy in the short- and long-term future. Among the prime benefits of remanufacturing are, of course, the ecological benefits, as it reduces the volume of materials entering the waste stream. Not only is there a reduction in the amount of product sent to be recycled, but the scrap which is sent to recycling from remanufacturers has a much better chance of avoiding contamination that degrades material quality. Further impacts on society are also discussed from both an economic viewpoint as well as the savings to be made in energy and raw materials.*

KeyWords: Recycling, Remanufacturing, sectorial analysis, ecological benefits, economic,

1. INTRODUCTION

In the Asia, and particularly in the India, recycling has become familiar in public and private arenas as a direct result of continued legislative pressures and public awareness efforts. However, recycling remains limited to simple items such as drinks containers, plastic materials, steel products and paper goods, in part because recycling a more complex product, like a vehicle, result in a loss of up to 95% of the value added in the initial manufacture of that product. Remanufacturing, on the other hand, is the ultimate form of recycling. While value addition the contents of raw material are preserved during the manufacturing process. It has the potential to contribute significantly to a more sustainable future, and has already begun to increase materials efficiency by reducing emissions of greenhouse gases. The the industrial process like remanufacturing used products can be restored and resued till its useful life. The proposed work decribes how products are designed to complete remanufacturing process. It also describes how the remanufacturing processes can be improved to be more efficient.

When comparing remanufacturing with other end-of-life scenarios, it is hard from an environmental perspective to determine which scenario is preferable. This research has shown that remanufacturing is preferable to new manufacturing from a natural resource perspective. Intially in remanufacturing the product shape is considered to retive form the loass. Furthermore, it has been found that it is environmentally and economically beneficial to have products designed for remanufacturing. To avoid obsolescence, the products must be easy to upgrade with new technology in the remanufacturing process.

Remanufacturing is essentially a form of recycling but offers additional benefits. The material is rescycled along with value addition in raw material also. When a product becomes defective, repairing it will more or less extend its useful life; remanufacturing will establish its next full life cycle. Unlike repaired products, which are returned to their original owner, remanufactured products are anonymous and ownerless until purchased. Remanufacturing activities are applied to a large number of products. These include:

Automobiles, Automotive Parts, Electric Motor, Tyre Single-Use Cameras, Personal Computers, Industrial equipment, Office Furniture, Compressors Telephones, Televisions, Electrical Apparatus, Vending Machines Photocopiers, Toner Cartridges, Data-Communication Equipment, Gaming Machines, Musical Instruments, Robots Different industry segments sometimes use other terms for remanufacturing. For example, 'recharged' is used for imaging products such as laser and toner cartridges and 'rebuilt' is for motor-vehicle parts and systems. Other related terms that refer to distinctly different processes include 'recycled', 'repaired', 'restored', 'reconditioned' and 'used'.

The Remanufacturing Institute (TRI) asserts that whether or not a product is remanufactured depends on the process utilized. According to TRI guidelines before manufacturing the below mentioned conditions must met-

- The principal components are reused.
- Dismantling is carried out so that it is possible to ascertain component condition, wear or deterioration.

- Each part is thoroughly cleaned and examined.
- Any broken, missing or damaged items are replaced by new parts, or reconditioned so that they are as new. The used products also can be considered if the are working functionally proper.
- Any necessary rectification by, for example, machining, rewinding or refinishing will be carried out to restore working condition.
- A refurbished product will operate to the same standard as a new one.

In this research, a generic remanufacturing process will be described with all included steps that are needed to restore the products to useful life. In order to make the remanufacturing process further efficient towards a new sustainable prospect, the products need to be adapted for the process. Therefore, the preferable products properties facilitating each step in the generic remanufacturing process will be identify. A matrix (RemPro) will be formulates to demonstrate the relation between each and every generic remanufacturing step and the preferable product properties. This sectorial analysis aims to build on this current thinking and examine the scope of the industry and its impact on the Asian economy in the short- and long-term future. Among the prime benefits of remanufacturing are, of course, the ecological benefits, as it reduces the volume of materials entering the waste stream. Not only is there a reduction in the amount of product sent to be recycled, but the scrap which is sent to recycling from remanufacturers has a much better chance of avoiding contamination that degrades material quality. Further impacts on society are also discussed from both an economic viewpoint as well as the savings to be made in energy and raw materials.

1.1 Environmental Issue With Remanufacturing In India

In the era of global climate change, when all countries have a moral duty to contribute towards green environment, remanufactured products can reduce carbon emission and provide better environmental safety to the nation and consumers.

Conventional manufacturing is unsustainable because of its significant adverse environmental impacts. Manufacturing generates more than 60% of annual nonhazardous waste and causes problems including pollution and shortages and therefore high cost of landfill space and virgin materials (Winifred and Ijomah, 2009).

Remanufacturing facilitates less consumption of energy and materials during production, and reduce waste, thereby contributing to sound solid waste management and environmental stewardship. Remanufacturing reduces Green House Gases, Raw Material Use, Landfill Waste, Energy Use, Water Use.

The existing environmental legislations like Environment (Protection Rules), 1986 – Rule 3A, Schedule VI, Annexure I, The Recycled Plastics Manufacture and Usage Rules, 1999, The Batteries (Management and Handling) Rules, 2001- Rule 4 are Not very compulsive/stringent (Mukharjee, 2009).

Information will be presented on the Indian remanufacturing industry, drawing on direct comparisons with the Indian market. This section highlights how enlightened remanufacturers are at the forefront of marketing novel product-service offerings, and shows how those sectors that compete on lowest price are suffering against lower-price competition, mainly from abroad. Although its societal benefits are clear, there are a number of obstacles to overcome before the full benefits of a remanufacturing programme can be appreciated. These will be discussed in this research. They will bring several issues to the fore, including the need for commitment from senior members of management to drive it through; the criticality of the product design to enable profitable remanufacturing; and getting involved in trade groups to learn about the latest remanufacturing issues and how they are likely to affect the business.

This research will provide extensive information on how remanufacturing is specifically being adopted into a number of key industries. These include automotive, aerospace, consumer electronics, ink cartridges, batteries, refrigeration and industrial machinery. The review looks at how remanufacturing has been implemented in each of these sectors as well as the benefits it has brought, both from an economic perspective and an ecological one. Examples of pioneering companies that are embracing the remanufacturing model are also included to provide further insight into its increasing appeal across companies of any size.

The review will be ends with a set of case studies featuring some of the largest global organizations. For instance, the case study on Fenco Automotive Parts shows the different stages involved in their remanufacturing processes, while examples provided on companies such as Caterpillar, Xerox and Ford illustrate how the efficiency of business operations can be dramatically improved by a well-structured remanufacturing program.

1.2 Aim And Objective

This is a need of time to explore how to make remanufacturing systems further efficient by changes in product and process design. In addition, a need to explore how to integrate environmentally significant product aspects, such as those that facilitate remanufacturing, into manufacturing companies was elucidated. Hence, the objective of this thesis is as follows:

To study how product and process design can contribute to effective remanufacturing and to explore the assimilation of design for remanufacturing aspects to the environmental management systems of manufacturing companies. The specific objectives of this thesis are as follows:

- To study the environmental and Sustainable perspectives on remanufacturing
- To study the generic remanufacturing processes also the design and methodology for remanufacturing.
- To study the societal impact of remanufacturing.
- To study the Indian remanufacturing industry.
- To identify preferable remanufacturing product properties
- To investigates the price versus quality of remanufacturing.
- To identify the challenges for remanufacturing.
- To analysis sector-specific remanufacturing.

1.3 Scope/Statement of the problem

Scope for remanufacturing towards a new sustainable prospect has increased where industries have embraced new technologies for the restitution of components. This has enabled greater material recovery and even the retention in-house of capabilities that may have previously been outsourced. The improvement in service and margin that this affords can offset loss of business through general enhanced longevity of industrial items. Remanufacturing has a high chance of failure when used to compete in markets where price is the only basis for competition, unless a low-cost source of labour is available ultimately it will insist the research on product and process design for effective remanufacturing towards a new sustainable prospect.

2. Research Questions

The research objective is rather wide and would require an enormous amount of research in order to be completely fulfill. To focus the research, this dissertation will address five research questions.
Since the objective includes finding remanufacturing processes that have environmental benefits, the first research question is stated in order to identify environmental issues related to remanufacturing. The research question deals with the environmental impacts occurring when products are remanufactured. Comparisons to other end-of-life scenarios e.g. The benchmarking is to be done with new products along with material recycling. The first research question is:

1. Is product remanufacturing for new sustainable prospect environmentally preferable in comparison to new product manufacturing and/or material recycling?

In order to design products for successful remanufacturing, it is crucial to identify the steps that are included in remanufacturing processes. Furthermore, it is of importance to adapt the products intended for remanufacturing for all of the steps in the remanufacturing process. A reason for doing this is to reduce the risks of having products adapted for only some of the steps in the remanufacturing process. Therefore, the second research question is formulated:

2. What steps are to be included in a generic remanufacturing process for new sustainable prospect?

When the remanufacturing steps of a generic remanufacturing process have been identified the design for remanufacture aspects must be elucidated. Each step of the generic remanufacturing has to be analyzed in order to investigate how remanufacturing could be facilitated by suitable product design. The results of the third research question will provide guidelines for how products could be adapted for the remanufacturing process. With this background in mind, the third research question is:

3. Which product properties are preferable for the remanufacturing steps?

In order to achieve technical and economic improvements of remanufacturing processes, the next research question address technical and economic benefits and obstacles. In addition, it further addresses the Efficiency of remanufacturing processes by viewing industrial processes from a lean production perspective. Furthermore, the analyzed remanufacturing facilities verify the results from research questions two and three. With this aspect of remanufacturing in mind, the fourth research question is stated:

4. How can remanufacturing facilities become more efficient?

The fifth and final research question continues the research based on the results of addressing research question three, where preferable product properties were identified. In order to achieve a better integration of design for remanufacturing aspects into manufacturing companies, the companies' environmental management systems were investigated. As stated in the introduction, product-related issues might not always be considered by the environmental management staff, and thus the fifth research question elucidates this issue further:

5. How can design for remanufacturing aspects be integrated into manufacturing companies' environmental management systems?

These five research questions are considered in several research subprojects and they also have a close relation to the appended remanufacturing case studies.

Research questions two and three primarily addressed in the research described in the author's Licentiate thesis (Sundin, 2002). There it was stated that there was a need to further verify the results through several industrial case studies. These were later performed in the case studies.

3. Academic and Industrial Significance

Although much research has been carried out in the area of remanufacturing and design for remanufacturing, few researchers have investigated what remanufacturing process Steps are to be included in a generic remanufacturing process. Furthermore, few have identified what product

properties those are preferable for the remanufacturing steps.

This research project contributes to an increase in knowledge and competence for designing remanufacturing processes within industry. It is also hoped that this research will facilitate the adaptation of industry to environmentally advantageous and efficient remanufacturing, and thus enhance the competitiveness of industry. Companies with knowledge and competence in remanufacturing have the potential for achieving market advantage over their competitors.

Experiences among the analyzed remanufacturing companies were exchanged, thus enhancing their knowledge within the remanufacturing area. These experiences from several remanufacturing businesses concern several areas, including process layout, obstacles, bottlenecks, product design adaptation etc., and serve as the foundation of this knowledge. Furthermore, these research results could spread knowledge to those companies that are planning to start or already perform remanufacturing. However, the knowledge should not only be restricted to a few large innovative companies; instead, this research will contribute with the spread of knowledge within the entire industry.

By remanufacturing products, material and energy used in production can be salvaged. In design for environment (DfE), it is common to find most environmental benefits by decreasing the energy use during the product use phase. Since environmental impacts are intimately connected to flows of materials and energy, and the most important flows, at least for manufacturing companies, are closely linked to products (see Ayres, 1994; and Berkhout, 1998), it now seems urgent for environmental management systems to encompass products and product development. Consequently, it was of great interest to illuminate how standardized EMS were related to DfE, e.g. to what extent they encompassed the products and product development procedures.

The exploration of DfE aspects in EMSs will cover an area of research that few have explored. It will also contribute to the debate of whether EMSs really improve a company's impact on the environment (see Ammenberg, 2003). As the number of standardized EMSs in world rises along with the research about them, this research will contribute to a better understanding of what impacts EMSs have and of the role of external auditors.

3.1 Limitations

There are, however, several limitations restraining this research and which cannot be determined in the scope of this research. These limitations are as follows:
When identifying what product properties were suitable for products aimed for remanufacturing, only two products were analyzed. By no of research finiding many derived properties are gathered. Several products could have been analyzed to strengthen these results.

Lack of time restricted the case studies at the remanufacturing facilities to short and rather high level investigations. In depth case studies would have required more time at each remanufacturing facility. The studies in Canada and especially in Japan, for example, did not allow for such in depth studies.

The number of analyzed remanufacturing facilities included in the remanufacturing case study was restricted to six. This six case studies are considered because of lack of resources, facilities and most important is lack of time. In any event, it is the opinion here that these six remanufacturing facilities have provided a valuable general picture of the remanufacturing business.

In most remanufacturing case studies, only the facility manager was interviewed. He/she gave a clear picture of the remanufacturing facility, but if several people had been interviewed some other valuable aspects might also have been discovered.

Furthermore, in the remanufacturing case studies, ideally the rapid plant assessment (RPA) should be performed by a smaller research team. In this research, one researcher (the author) filled in the RPA in collaboration with the facility manager.

In the exploration of the auditors' role in the integration of DfE in EMSs, the researchers choose to only interview Swedish auditors. This was a decision of convenience and time saving, since the travel distances were short and sometimes two interviews could be conducted on the same day.

3.2 Delimitations

Delimitations are research restrictions determined by the researcher. This research has much delimitation since the area is wide and needs to focus on a narrower scope. Therefore, some parts that might be interesting to conduct research on must be excluded. These are the delimitations for this research:

Delimitation is made over which theoretical areas to base this dissertation research. Therefore, the theoretical foundation includes industrial ecology, environmental management systems, product recovery, reverse logistics, product development, design for environment, design for remanufacturing and remanufacturing.

When conducting the environmental analysis at Whirlpool India Ltd. Ranjangaon, Pune (Case Study 6) several scenarios could have been analyzed in order to achieve a better picture of the environmental concerns of the company's remanufacturing. Within this research focus have been put on products that have a certain degree of complexity

regarding product structure materials etc. Products such as glass bottles have not been considered.

4. RESEARCH METHODOLOGY

As one can see of the research question's nature, they are mainly of explorative nature starting with the word 'how'. Most of these research questions have chosen to be addressed with a case study perspective according to the following table, furthermore, when conducting environmental, technical and economic analyses more specific and suitable data collection have been chosen.

Form of research question	Strategy
How, Why	Experiment
Who, What, Where, How much, How many	Survey of archival analysis
How, Why	History
How, Why, What	Case study

As per the research question for this dissertation appropriate research methodology will be select which may include:

1 Interviews
2 Life Cycle Assessment
3 Activity Based Costing (ABC) – methodology
4 Rapid Plant Assessment (RPA)
5 Case Study Methodology

This study focuses on manufacturing industries and the means for them to strive towards a more sustainable development. By keeping sustainable development in mind, manufacturing companies are forced to satisfy customer needs in a manner that leads to, from a life cycle perspective, less raw material extraction and consumption as well as energy consumption. One of the means to achieve this is to adapt the products for product recovery, where parts of the product or whole products can be reused once again after being used. The linearity in material flow is replaced by closed loop as linearity can dominates consumers. It is important to view these flows as circular instead of linear. Also the testifies herein documents existing barriers related to (1) manufacturing metrics and measurements and (2) manufacturing process modeling that can support sustainable manufacturing. Findings are based on an industry perspective (focus groups) and academic perspective (literature review). Strategies for overcoming the barriers, including standards development are presented from both perspectives.

5. CONCLUSION

Remanufacturing has a not so long history in the India, and continues to be practiced across a whole range of industrial sectors, some growing and some in decline. Theoretically, remanufacturing can contribute to more eco-efficient and sustainable product systems. However, the contribution that remanufacturing can make will be limited by the suitability of products for remanufacturing. It is widely acknowledged that remanufacturing has the potential to make quantifiable impacts on the level of sustainable consumption, and there are steps that all stakeholders can take to enable this. Foremost among these are the elimination of legal impediments such as

1) Denial of access to manufacturer design information

2) Banning of remanufactured components in new goods

3) Redefinition of what constitutes waste.

Removal of these will increase competition and force the evolution of improved services including remanufacturing. If remanufacturing is to be more widely adopted there will need to be a push for freedom of information, a lifetime warranty to spur design fitness, and a liberalization of the distinction between waste and resources to

encourage trade in exploitable materials. Further success of remanufacturing will also entail concerted efforts by companies and industries to maintain high quality standards and establish a solid reputation for quality through branding

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