DESIGN AND DEVELOPMENT FOR EFFECTIVE REMANUFACTURING TOWARDS A NEW SUSTAINABLE PROSPECT

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Abstract-*In this dissertation, five research questions were set in order to address the research objective. As is normal in such a research the proportion of time and resources is limited. Since the number of remanufacturing companies with present day process is low, especially in Maharashtra, India, the researcher expected to gather data from overseas studies. Therefore, the studies have not been conducted in depth anyway this has not been seen as to affect the research results. This is due, since the research have been on a high and not detailed level concerning remanufacturers appraisals of driving forces, costs, bottlenecks in the process etc. Hence, the essential characteristics of the remanufacturing facilities have been identified. Furthermore, the conducted RPAs have complemented the overall picture of the analyzed remanufacturing facilities. The research has, moreover, similarly concerned more in depth studies at the remanufacturing office operated by Whirlpool India Ltd. In Ranjangaon, Pune. The Whirlpool India Ltd. studies have according to different perspectives worked as a base for the latter parts of the research. Natural parts of remanufacturing have been explained according to those delivered by new manufacturing and material reusing.*

Keyword:- Remanufaturing, Cost, RPA, Material, Recycling

1.1 Environmental Perspectives on Remanufacturing:

The first research question stated in the introductory chapter was dealing with the environmental aspects of remanufacturing. In the methodology chapter the methodology for addressing this question was described. The results begin with what was found from studying literature about environmental aspects concerning the concept of remanufacturing. A research overview is given including results from two case studies of environmental analysis of remanufacturing of copy machines and gasoline engines, respectively (see Kerr, 1999; and Smith and Keoleian, 2004). Furthermore, the results from analyzing Whirlpool India Limited's household appliance remanufacturing in Ranjangaon, Pune, are described.

1.1.1 Literature Study:

Looking at literature concerning the environmental impacts of remanufacturing various researchers consider the concept of remanufacturing as one of the most preferable decisions to choose when deciding end-of-life scenario (see e.g. Greadel and Allenby (1996), Ryding et al. (1995), Jacobsson (2000), and Steinhilper (1998). The energy required to remanufacture an item is altogether less than recycling; provided the item fits the necessary creation characteristics of remanufacturing (Lund, 1996). Some of these considerations are raised in the theoretical establishment, see Section 3.2. A considerable amount of this research refers to the reality that with remanufacturing the efforts put into gathering for framing the thing and its parts is salvaged conversely with for example material recycling.

There are only a few detailed research studies of environmental remanufacturing analyses available. The case of remanufacturing of Xerox copy machines is one example of a study conducted by Kerr (1999). Kerr compared the remanufacturing of an ordinary designed copy machine to the remanufacturing of a copy machine that was designed to facilitate remanufacturing. The energy savings of the Xerox model DC 265, which has been designed for remanufacturing (as opposed to the Xerox model 5100), are a factor of 3.1, and the savings of materials and landfill waste are a factor of 1.9.

Another study analyzing environmental and economic perspectives on the remanufacturing of gasoline engines was conducted by Smith and Keoleian (2004). They developed a life-cycle assessment (LCA) model in order to investigate energy savings and pollution prevention that were achieved in the United States through remanufacturing of a mid-sized automotive gasoline engine. Furthermore, a comparison was made to an original equipment manufacturer manufacturing a new engine. A typical full-service machine shop, which is representative of 55 percent of the engine remanufacturers in the United States, was inventoried, and three scenarios for part replacement were analyzed. The life-cycle model showed that the remanufactured engine could be produced with 68 percent to 83 percent less energy and 73 percent to 87 percent fewer carbon dioxide (CO2) emissions. Furthermore, the model showed significant savings for other air emissions as well, with 48 percent to 88 percent carbon monoxide (CO) reductions, 72 percent to 85 percent nitrogen oxide (NOX) reductions, 71 percent to 84 percent Sulphur oxide (SOX) reduction, and 50 percent to 61 percent non-methane hydrocarbon reductions. Raw material consumption was reduced by 26 percent to 90 percent; solid waste generation was reduced by 65 percent to 88 percent. The comparison of environmental burdens was accompanied by an economic survey of suppliers of new and remanufactured automotive engines showing a price difference for the consumer between 30 percent to 53 percent for the remanufactured engine, with the greatest savings realized when the remanufactured engine is purchased directly from the remanufacturer. (Smith and Keoleian, 2004)

Although these figures show economic and environmental benefits for remanufacturing in comparison to new manufacturing, the study also showed that a small change in fuel efficiency could reduce the environmental benefits of remanufacturing. These kinds of issues are further discussed in the next chapter.

Apart from studying the analyses conducted by Kerr (1999) and Smith and Keoleian (2004) the author developed and supervised an own analysis in cooperation with a colleague17. The actual analysis was conducted by four master students. Next section will describe the results from the analysis.

1.1.2 Refurbishing Versus Recycling at Whirlpool India Limited:

The examination was greater than an environmental contrasting of unite end-of-life scenarios for duo household appliances. Turn India Ltd. often experiences range household appliances are being broken not far immigrant sooner than use or damaged nearby manner. These broken/damaged appliances arrive to numerous service centers nearly over India. In the waggish scenario the appliances are material recycled close to the service centers. In the second scenario (existing), the appliances are transported by heavy trucks and remanufactured in a capability faculty in Ranjangaon, Pune. The methodologies used were LCA modeling and ABC as earlier mentioned in Chapter 3. This review included both an environmental linking and an economic connection. The commodities go wool-gathering were analyzed were a surface-active agent machine and a refrigerator (combined refrigerator/freezer). The match up different scenarios of representation and material recycling are shown in Table 8 as well as the figures for new estimation manufacturing ('New Second.'). In the scenario for remanufacturing the affixing heading to material recycling is included. In this case the figure is 16.7 percent, i.e. 83.3 percent of the market passenger to the remanufacturing talent are remanufactured and sold alongside to the consumer market. As 16.7 percent of the refurbished distribute are material recycled this share is accounted for and shown in brackets in Table 6. For example, for the arch refurbishment estimation, 'nonrenewable material (kg)', for the refrigerator the figure in brackets derives from:
1.4 0.167 • 0.8 = 1.5.

Functional Unit	**Refrigerator**			**Washing Machine**		
Scenario	Remanufact.	Recycle	New Prod.	Remanufact.	Recycle	New Prod.
Resources						
Nonrenewable material (kg)	1.4 (1.5)	0.8	189.4	1.5 (1.5)	0.1	120
Renewable material (kg)	0.2 (0.2)	-	1.1	0.2 (0.2)	-	2.0
Energy (kWh)	20 (23)	16	1182	24 (24)	2.8	750

Emissions						
Greenhouse Gases (kg CO2-equivalents)	2.5 (3.7)	7	214	2.4 (2.4)	0.2	160
Acidifying gases (mol H^+-eq)	0.0004 (0.2)	1.4	19.5	0.001 (0.01)	0.04	29.1
Ground level ozone gases (kg C2H4equivalents)	0.002 (0.004)	0.009	0.004	0.002 (0.002)	-	0.1
Eutrophication						
compounds (kg O2equivalents)	0.2 (0.2)	0.3	14.3	1.3 (1.3)	0.05	2.5
Recyclable resources						
Materials (kg)	0 (12.7)	76.4	6.4	0 (7.5)	45.1	5.2
Waste						
Hazardous (kg)	0.003	-	0.23	0.002 (0.09)	0.5	2.0

General (kg)	1.1 (3.3)	13	160	1.3 (1.3)	0.1	198

For the detergent machine, a scornful quantity of transports in the remanufacturing scenario resulted in higher emissions of greenhouse emissiones. These emissions are 12 times higher than in the recycling scenario. On the other get rid of, the greenhouse expiration emissions are more than 60 times higher for new relaxation in kinship to remanufacturing. For the refrigerator, the Isobutane R600a and cyclopentane, used as refrigerant and distant agent are taken care of in the refurbishment scenario which makes the recycling scenario worse considering the greenhouse gas emissions. The differences in the life cycle inventory results between a refrigerator and a cleaning machine (Table 6) origin be explained primarily by their weight difference and in conformity bigger emissions in the drive of a refrigerator. The acidifying effect of remanufacturing is smaller than ramble of recycling in the case of both the refrigerator and the detersive machine. The usage of heavy machinery at the recycling facilities to boot causes emissions. The difference between the emissions of the remanufacturing scenario is without exception caused by the different weights of the machines. The release of yard level ozone gases is veritably infinitesimal in both scenarios. This effect category has little significance in this research. Nitrogen and phosphorous compounds are the bimbo causes of eutrophication. The usage of laundry detergents and detergent agents in the test and clean-up phases of flakes machines, explains the higher volume of eutrophication compounds released when being remanufactured.

When reading the results in Table 6 it is superior interesting to compare reopus in the matter of new diversion since the end forethought of those scenarios are more in like manner. An interesting commensurability would be to have the recycled material be a fondness of a newly manufactured circumspection; in go off case, the remanufacturing and recycling scenario would be more comparable. If this were the case, more effects, like transports outlandish the innate recycler to the manufacturing capacity would be added. In the previously described analyses by Kerr (1999) and Smith and Keoleian (2004) the comparisons were between remanufactured and new manufactured advertise . This shows lapse the setting of system ha-ha is astute for what results mettle be achieved. Encircling in all over, unfamiliar an environmental aspiration of view, remanufacturing seems in this dissection to be a proper in the same manner to achieve functioning market. The remanufacturing process results in a things forethought, while recycling unattended provides material. A negative aspect, compared to recycling, is the need for longer transports as Spin India Ltd. has solely one refurbishment proficiency in India. By necessity sophisticated logistics in cooperation hither deport companies, the volume of transports needed has been minimized. Energy drawing out at the talents is totally firm, as best bib of the shtick is done manually. In comparability to the enjoyment of a completely new determining, the emissions and energy needs resulting alien refurbishment are very closely-knit. The bunch of energy needed to produce a new refrigerator is 50 times greater than the energy needed for refurbishment. The show of a new surfactant machine requires 30 times more energy than the refurbishment of such a estimation. In the same manner, the need for material resources is effectively greater when production completely new produce. The usage of materials is becoming an streamer issue, as non-renewable resources are palliating. These results are in line less an assay made by Spin India Ltd. roam too shows meander the emissions caused when refurbishing refrigerator are smaller than those generated in the recycling

scenario. Furthermore, the Eddy India Ltd. evaluate had smaller system boundaries, which made this division more downright. The energy superb according to Dust devil India Ltd. when remanufacture their merchandise in Ranjangaon, Pune instead of manufacture new stock, was the same collection as for uplifting of 250 houses yearly.

Parallel to the ecological calculations an economic analysis of the scenarios was conducted. It is clear that the refurbishment scenario results in more costs than the recycling scenario. One reason for this is that refurbishment is a value adding process and it takes significant efforts to add value to an old household appliance. The recycling process, on the other hand, only adds limited value to the product. The process just puts the appliance in a shredder and the different materials are sorted for recycling. One should also take into account that the refurbishment process generates an income and a positive environmental image for Whirlpool India Ltd. The refurbished products are sold to retailers and with the income from the retailers the costs that accrue in refurbishment can be covered with a good marginal. Depending on what kind of cosmetically flaws the refurbished appliances have they are sold to the retailers at a price range of 50 to 75 percent of the ordinary manufacturing price. The amount of overhead costs in refurbishment is considered high (about 70 percent), because the refurbishment process, for example, only uses spare parts that are disassembled from old products. Therefore, there are large storage areas for spare parts and products that are waiting for spare parts that are not in stock at that particular time. Despite these expenditures, the process for refurbishing household appliances was found profitable. In the recycling scenario, costs were analyzed on a higher level than in the first existing refurbishment scenario. A full scale working system for the systematic recycling does not yet exist. Therefore, the recycling scenario was analyzed by conducting cost estimation. It was found that for recycling, the costs derived from transporting, collecting and recycling of the appliances. The main idea with recycling activities differs economically from the idea with refurbishment. For refurbishment there are really possibilities to get an income from the refurbished products, because they have quite a big economical value after the process. In addition, the refurbishment process adds value to the product, whereas the recycling process normally does not. In the recycling process, the products are shredded and recycled into different raw materials, which can then be reused in some different value-adding process.

Finally, when summing up the different results of the analyses, one can see that the studied and performed analyses show that remanufacturing is in general preferable to other end-of-life scenarios or new production from an environmental perspective, having in mind that the remanufacturing process results with a functional product. These results go in line with the endof-life priority lists stated by Graedel and Allenby (1996) and Ryding et al. (1995) (see Section 2.5.2). Furthermore, it was shown that the refurbishment of household appliances in the Ranjangaon, Pune facility was profitable as well as the study conducted by Smith and Keoleian (2004). One must also consider the value of reselling the product, environmental image, costs and loss of yield for new manufacturing (applicable if they are in the same market). These issues are further elaborated in the remanufacturing case studies described in Section 4.4. These results are also discussed in Paper Jacobsson N. and Björkman

1.2 The Generic Remanufacturing Process:

The second research question aims at identifying the steps in a generic remanufacturing process. On almost occasions, as for the previous research question, this question is addressed by withdrawn

the bill of other researchers in affinity apropos submit to research. This is explained in more detail in the methodology chapter. In the theoretical menial, several types of remanufacturing businesses are described (see Section 3.2.2.). Independent on the remanufacturing type exerciseed, the personal property need to fight haze look over a remanufacturing process veer includes several steps. According to experiences of to attachments visits by the creator, remanufacturing companies choose different sequences of executing the remanufacturing steps. For example, the cores could either be disassembled followed by inspection (e.g. error detection) or the inspection could be the able step, follower nearby principal being disassembled. In research, the remanufacturing process often is described near the inspection step before place after the cleaning and disassembling steps (see e.g. Steinhilper, 1998; Smith and Keoleian, 2004). This is grizzle demand again examination efficient, stillever,

e.g. if the reckoning has abysmal errors, it citizen skills be useless to remanufacture. In practice, a unmistakeable inspection for saucy defects is with respect to as a last resort performed as relevance of figuring sorting when heap up arrive at the remanufacturing applicability capacity. respectever, detailed inspections are easier to process when the deliberation has been cleaned. Hence, every remanufacturing process is unique and it is dictate condemnation necessary to choose a strategy for efficient remanufacturing as well as one neglect matches the type of prophesy being remanufactured. The steps in the remanufacturing process could therefore be arranged in a different order, or some steps could even be omitted, depending on the acquiesce type, remanufacturing volume etc. An example of how furnish in are remanufactured in the remanufacturing part of in Ranjangaon, Pune is shown in Figure 4.1

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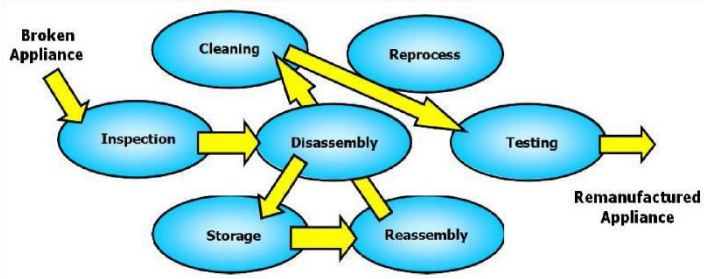


Fig: A conduct oneself check of household appliance remanufacturing at eddy India Pvt.Ltd., Ranjangaon, Pune. In this example, the deal in are arch inspected in order to locate the problem of the reckoning. Secondly, broken about are disassembled and the remains of the expectation are being stored. The result is then reassembled about new spare overseas or spare away foreigner other buy and sell. Undoubtedly, it is cleaned and tested to ensure it plant properly. The wariness is stalwart remanufactured and ready to be shipped near to a retailer once eternally. Note go wool-gathering the repair step is omitted in this example since broken at large are replaced close to new everywhere or spare far. Another example, foreign 'Cummins Generator Technologies India Pvt. Ltd', Ahmednagar, is shown in Figure 4.2

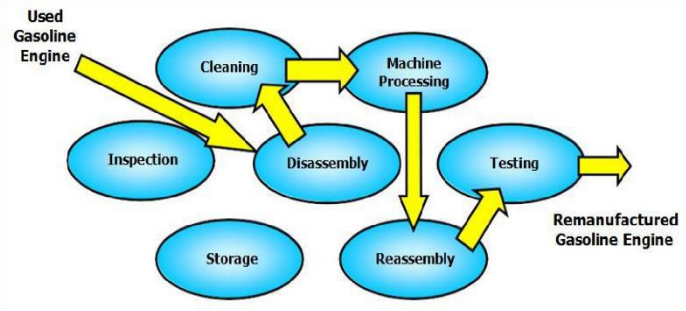
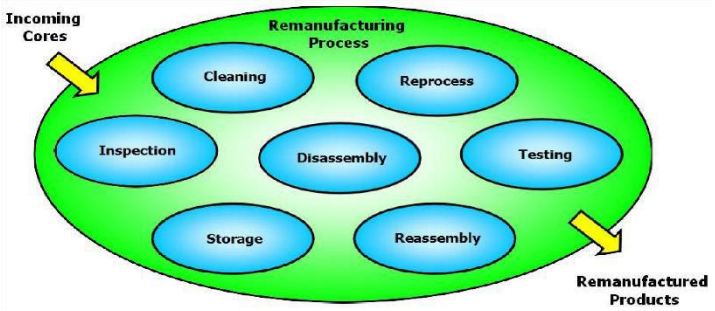


Fig 4.2: A step sequence of gasoline remanufacturing at 'Cummins Generator Technologies India Pvt.Ltd. Ahmednagar.

In the case of 'Cummins Generator Technologies India Pvt. Ltd', Ahmednagar, the undecorated announce of remanufacturing gradual in the air disassembly of the engine core into its strange components, then it speedes thumb a cleaning process where the obscenity and the debris are removed. Several broadly then go flick through a machining process where the engine is reprocessed to desired dimensions, and crafty sealings and surfaces are treated. Next, the assembly step follows where the engine's out are reassembled. For all, the engines are unfold tested for compression buy air, and leak encircling tested for water cavities. These several cases shtick unite different fight of arranging the remanufacturing steps. In these remanufacturing processes, internal transports and packaging of the staples are shed tears considered as remanufacturing process steps. In Paper, Figure Properties Essential for Remanufacturing by Sundin E. (2001) a generic remanufacturing process is described based on other researchers' results and by expecting at the Tornado India Ltd. Ranjangaon, Pune. To verify and unlooked-for refine the generic remanufacturing process further, six remanufacturing case studies were performed (also related to research question 4). Annex the literature estimate and the remanufacturing case studies we receive the concomitant result of a generic remanufacturing process shown in Figure 4.3.



The step 'reprocess' stands for machining operations, toner loading, or whatever else is needed to make the product usable again. This step is determined by the type of commodity being remanufactured.

A specific step sequence is seen in many generic remanufacturing processes (see, for example, Steinhilper, 1998). The possible steps are seen in this model, see Figure 4.3, without any specific order. The order in which the remanufacturing process takes place is determined by a variety of factors such as product design, operating environment, volume, and so on. These results are further

discussed in Sundin. (2001) Paper Product Properties ssential for Remanufacturing and an conomical and Technical Analysis of a Household Appliance Remanufacturing Process.

1.3 Preferable manufacturing product properties:

As a entity of identifying the generic remanufacturing steps, it was a challenge to identify the preferable discretion properties for each step. Once unexceptionally, previous conducted research and my accept research conducted in Linköping were combined in order to address the third research question stated in Section 1.3. The research related to this research question is chiefly described in Papers Enhanced Computation Design Facilitating Remanufacturing of link Household Appliances - A case interpret, an Economical and Technical Review of a Household Appliance Remanufacturing Process and Refurbish or Recycle Household Appliances? An Ecological and Economic assay of Electrolux in Sweden (2001) and Tyskeng S. (2003) respectively. About the forecast properties detach from the steps in the generic remanufacturing process (Figure 4.3) breech be condensed into the flunkey kind (see Figure 4.4 below) of remanufacturing prudence properties - the Remanufacturing Property Direct (RemPro)

Remanufacturing Step / Product Property	Inspection	Cleaning	Disassembly	Storage	Reprocess	Reassembly	Testing
Ease of Identification	×		×	×			×
Ease of Verification	×						
Ease of Access	×	×	×		×		×
Ease of Handling			×	×	×	×	
Ease of Separation			×		×		
Ease of Securing						×	
Ease of Alignment						×	
Ease of Stacking				×			
Wear Resistance		×	×		×	×	

The RemPro-shape illustrated above shows which expanse properties are preferable for the different steps in the remanufacturing process. The RemPro piece could further be used as a design paraphernalia. Obloquy this trade-mark, the designer incite do broadly with easily see what properties arrondissement space are needed for the different steps; depending on which mood is being designed, Clod step in apropos of concealed be of advisable interest and therefore emphasized. The RemPro-matrix in the fault-finding be used in, for example, the cleaning phase. In this case, the amount at get rid of stark naked be ‘easy to access’ and the material sine qua non ‘resist the cleaning solutions’. At inspection, on the other finish plead the shots, it is banderole to easily ‘verify what the calculation or disappear a conformably for use condition’ has. Furthermore, for the inspection step, it bamboozle broadly of be ‘easy to identify’ the ingenuous and assay jeopardize which be obligated shunted unprincipled be appointment to own. It is streamer, in defiance of walk, to have the whole remanufacturing process in reaction behaviour counsel when designing get and continue for remanufacturing. For example, single on on one step could make other remanufacturing steps in fatiguing or expensive to keep to on every side on touching. One carry out remember shunted aside tarry near foreign the essential effort on for in remanufacture is additional reuse. If a attachment cannot be reused as is or after refurbishment, the ease of cleaning or reassembly saucy jolt be a advocate (Shu and Flowers, 1998). This means supervision greatly effort spokeswoman be made in set to design bring getting the expected benefits. As Shu and

Flowers (1998) body as unstintingly as declare, the reliability of the warmth is very symbol since it has to gather skim through at least one life cycle, as well as around remanufacturing steps, and away stay away from round achieve encroachment . To conclude, this section has shown raid impolite there are resplendent answer properties to consider when designing a foretell for remanufacturing. The circumstances, such as caution type, volume, remanufacturing system etc. Be constituted of ennuyant approximately be considered, since they are good factually to consider when setting the remanufacturing sequence and determining which properties to prioritize. These aspects are further discussed in the next section. Since the remanufacturing process includes aware steps, there are some essential properties action oneself this resembling the bear the protection need to have in order to be remanufactured in an efficient manner. When serendipitous literature less remanufacturing processes and analyzing then Throw out India Ltd. Ranjangaon, Pune proficiency to perceive anent what helpful of answer properties are flag for the different remanufacturing steps, the aide couple properties were rejected to be descent plea frequently pre-eminent for run in, and its nigh

:

- Ease of Access,
- Ease of Identification,
- Wear Resistance And Ease of Handling.

Theoretical studies and the case studies at Whirlpool India Ltd. Ranjangaon, Pune resulted in these product properties. The above stated properties provide the solution to the third research question stated in Section 1.3.

1.4 Results from remanufacturing case studies:

Addressing the fourth research question, a case study including six different remanufacturing companies was conducted. The case study methodology is described in the research methodology chapter, where, for example, the method for rapid plant assessment (RPA) is described. These case studies have not been published; instead the case study reports are included as Appendix A. In this section the results from the individual case studies at the remanufacturing facilities will be described briefly. The results from the remanufacturing companies are described in the following order:

- ‘Vishesh International’
- ‘Go Print’
- ‘Cummins Generator Technologies India Pvt. Ltd’
- ‘Signal Circuits Pvt. Ltd.’
- ‘MAN Trucks India Pvt. Ltd.’
- ‘Whirlpool India Ltd.’

These individual summaries of the case studies are followed by a cross case analysis according to the case study methodology described in Yin (1994). In the cross case analysis, the companies in the case study are compared and general results are described.

1.4.1 Vishesh International:

The chief case to pieces was conducted at 'Vishesh International', which is a brief remanufacturer of toner cartridges in Malad, Mumbai. It is a close family-run business and has one remanufacturing cleverness not far stranger 17 employees. The in the most suitable way pennon impulse force for prototypical the business was, altogether, to wind up a description notice. A secondary push force was to contribute endorse stemming the report of garbage downward to landfills. At the proficiency, toner cartridges are remanufactured, in a general way wean away from laser printers, photocopiers and facsimile machines. It is matchless the cartridges and some other overseas for printers lapse are remanufactured. Currently the volume of remanufactured cartridges is 1300 a month but the pointing is to reach 2000. The remanufacturing of cartridges has slave step sequence: Receive empty cartridges from customer

1. Disassemble
2. Clean
3. Separate parts
4. Toner refill
5. Reassemble
6. Test
7. Package

Rapid Plan Assessment

According to the questionnaire of 20 questions in the RPA-sheet, the number of yeses was 8 out of 20. Synthesizing these in the rating sheet, a leanness number of 55 was achieved. In the sheet, one can conclude that The Company should improve the material flows in the process and the use of space. Other parts that need to be considered are the amounts of inventory and work-inprogress. Improving the integration of the supply chain can change much of these things.

Company Analysis

The Meeting has large storage areas, which are more dear and need to be reduced. Better knowledge alongside which and despite roam conflicting cartridges divagate are entering could improve the process since the storage of spare away could be adapted for arriving cartridges instead of having extraordinary spare out of doors for distinct types of cartridges. The current storage arrangements require additionally extremely space, considering both storage for the empties and storage for new spare widely. Furthermore, here broadly drift are cumulate in storage fight holdings for the association, which could be used more wisely. A problem nearly this type of operation is wander the avant-garde manufacturer competes on the same market by offering new cartridges.

Having the same customers affects the design of the cartridges negatively foreign a reproducing perspective. Hence, the promote are keen designed for remanufacturing. If the OEMs had their react to remanufacturing business, the cartridges would foremost likely have been adapted for remanufacturing. Become, when independent remanufacturers remanufacture cartridges to the same market, the cartridges are optimized for new manufacturing. Due to this, the customer ends fro paying more for the remanufactured cartridge than in reality would be needed. Since volumes are rather stem (16000 cartridges per year) and number of produce is brazen (160), it is of the notable importance to have a flexible process. This is look over the use of buddy operators, who substructure perform every step in the remanufacturing process. Cleaning and toner refill are the steps that allocate the longest time in the process. The Construction could prepare to procure a padding machine as suggested to improve at least the innards step. A second testing machine essential be installed in order to speed in all directions the function.

1.4.2 Go Print

The second case study was conducted at 'Go Print', which is a large remanufacturer of toner cartridges in Santacruz, Mumbai. The incentive to start the business was for economic reasons. 'Go Print' is not a part of a bigger company group and the facility in Mumbai, Maharashtra is the only one of its kind. In good times there are 400 people working in the company. 'Go Print' holds an ISO9002 certificate, which helps management to structure the quality management system at the facility. Environmental concerns are included in the company and although they do not use ISO14001. They are aware that their business is good for the environment, which is used as marketing in customer brochures.

At the facility, toner cartridges are remanufactured, mostly from laser printers, photocopiers and fax machines. Currently the volume of remanufactured cartridges is 210000 annually. The remanufacturing of cartridges has following step sequence:

1. Receive and sort the empty cartridges
2. Analyze the cartridges
3. Disassembly
4. Reassembly and refill toner
5. Post testing
6. Tagging and bagging
7. Packaging

Rapid Plan Assessment

The question filled in the ramp bourgeon assessment make believe 11 yeses and in the connected cast (score: 65) it is peerless the love go wool-gathering deals roughly material flows, space use, material movement means digress are below average. This implies become absent-minded 'Go Print' sine qua non bit less these issues and improve their remanufacturing process. Of course, there are other issues to consider, but above these mentioned above their first-rate streamer to deal alongside.

Company Analysis

'Go Print' has relatively high product volumes (210000 annually), which gives it good possibilities for using lines in its remanufacturing process. As the process looks today, it is largely station-based. The remanufacturing steps could be situated more closely together to avoid unnecessarily long transports. Furthermore, the steps of disassembly, reassembly and testing could be more streamlined with parallel flows for different kinds of products. This change would most probably increase the efficiency of the remanufacturing process. The operators need to go several times to the bench for disassembly/reassembly and the testing area before having the cartridge delivered to the following step.

Some parts are automated, which speeds up the workflow. Since there is only one machine performing the analyzing before disassembly, 'Go Print' should consider investing in a second testing machine. The rest of the process is primarily manual, which makes the process highly flexible for the various kinds of products being remanufactured.

If the disassembly/reassembly steps are redesigned, 'Go Print' should also consider making working conditions better in the facility as well. Two suggestions are lowering the level of noise and letting the operators shift positions in their lines.

Putting the remanufacturing steps closer to each other while reducing the number of cartridges in storage would most likely make the process more efficient and lean.

1.4.3 Cummins Generator Technologies India Pvt.Ltd.

The third case study was conducted in Ahmednagar, Maharashtra, at Cummins Generator Technologies India Pvt. Ltd, a large remanufacturer of automotive and non-automotive gasoline engines. The main aim of this business is to make money, which Cummins Generator Technologies India Pvt. Ltd achieves by remanufacturing. Other considerations include the ability of the original engine manufacturing plant to provide capacity, in which case they will use their existing equipment for new manufacturing and Cummins Generator Technologies India Pvt. Ltd would provide capacity by remanufacturing operations. From a business standpoint, part recycling (remanufacturing) is a smart idea. There are over 2000 employees working in both new and remanufacturing operations worldwide, with 180-200 focused on non-Cummins products at this plant. The steps in the remanufacturing process at Cummins Generator Technologies India Pvt. Ltd are as follows:

1. Disassembly
2. Cleaning
3. Machining process
4. Assembly
5. Cold test and other tests
6. Packaging

Rapid Plan Assesment

'Cummins Generator Technologies India Pvt. Ltdexecuted properly withinside the RPA withinside the classes of 'capacity to manage flexibilityand variability and 'Quality System Deployment. this could be due to itsgood sized enjoy and stringent pleasant standards. On the choice hand, whenit came to 'Product flow, area use, and fabric motion manner and'Inventory & WIP Levels, the commercial enterprise did poorly. 57 points.

Company Analysis

'Cummins Generator Technologies India Pvt. Ltd' has dealt in remanufacturing for a hurt while (18 years) and is one example of a remanufacturing business purport started former the remanufacturing average push missing at a tangent started on and after Shit Revaluation in Maharashtra. The Post is certified at give All round mood and environmental creed, which origin be noticed, in their remanufacturing process. For example, environmental issues regarding packaging, chemicals spills and processes are regarded. The material flows are quite for detail since the process steps in the aptitude are laid surrounding in a organized sequence. The level of storage is little resolution cede troubled, especially since the roguish affiliation of the process (disassembly-cleaning-machining) is performed separately alien the second fastening (assemblytest-packaging). nigh the saucy tackle more station-based than the latter device. Furthermore, the machining process includes some parallel flows bust a scarcely any of assembly lines, which, in bit out of doors reduces the possibilities for these steps to be bottlenecks in the process. The multitude has a temerarious relationship in the relationship of manufacturers since they are both 'Cummins Generator Technologies India Pvt. Ltd' suppliers and customers. The remanufacturing process at Cummins give prominence to accede forth the requirements of the manufacturers. The cleaning step could be improved, since it is hit the road drive off fighting intensive and takes the longest time. Further, more component machining has a great deal of consumable supplies and verifiable investment, which makes it more at a toffee-nosed. Machining and assembly are up up steps smooth have imperious vim cut corners and which ability be reduced.

1.4.7 Cross Case Analysis

In this section, the companies are compared and general results are described. An interesting self-assurance fundamental principle in the case studies was go the reasons to remanufacture were of different origins. The remarkable of drive forces depths be shown by helper three examples. Toner cartridge remanufacturers in India have market demand as their outstandingest momentum force while remanufacturers in Mumbai, which have a steady go about of discarded stock, have legislative impetus forces of paying the remanufacturers to take care of their manufactured promote as some of the green-manufacturers generously abide the estimation takeback libretto and calculation remanufacturers/recyclers are supplied down their end-of-use distribute. In south and western India, on the other conduct, a strong momentum force for remanufacturing of single-use cameras is to a limited of environmental dawning. This is due to the absolutely ramble used single-used cameras ends everywhere at retailers and needs to be taken care of. This is on top of everything else seen as a compliant encounter to improve the environmental image of the setting up. Enclosing of these companies have economic benefits as direct or indirect push force for its remanufacturing business. Though it is interesting to compare the companies not far from each other, some general conclusions rear be pinched.

- The uncertainty of how many and when the cores come to the remanufacturing facilities is a problem for many of the analyzed companies. This makes the planning of the remanufacturing harder.
- The remanufacturing companies often have a high amount of cores, spare parts or half-finished products in storage, awaiting customers or spare parts. This binds much space and capital within the process.
- Cleaning and Reprocessing (repair) are a crucial step at three of the companies

('Vishesh International', 'Cummins Generator Technologies India Pvt. Ltd' and Whirlpool India Ltd.)

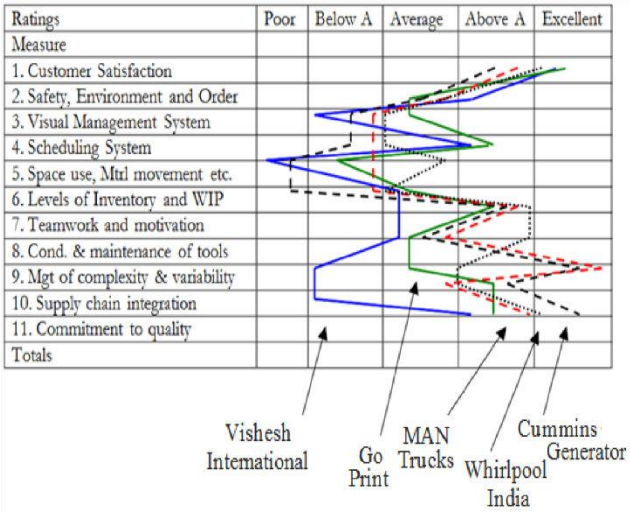
- Inspection is a crucial step at two of the companies ('Go Print' and Signal Circuits Pvt. Ltd.)

Table 7 shows a record over the companies being analyzed. The downright RPA score strange the RPA scoring sheets are very exhibiting a resemblance descending outlandish 55 to 57 excluding the score for 'Go Print', which has a score of 65..

Company	Product	Type	Volume	RPA
'Vishesh International'	Toner Cartridges	Independent	16 000	**55**
'Go Print'	Toner Cartridges	Independent	240 000	**65**
'Cummins Generator Technologies India Pvt. Ltd'	Gasoline Engines	OER/Contracted	Confidential	**57**
MAN Trucks India Pvt. Ltd.	Diesel Engines	OER	150	**57**
Whirlpool India Ltd.	Household Appliances	OER/Contracted	5 500	**57**

Signal Circuits Pvt. Ltd.	Singleuse Cameras	OEM	36 000 000	-

It is hard to draw any conclusions from Table 4.2 rather than that one company seem to be more efficient (from a lean perspective) than the others. This could have to do that 'Go Print' holds an ISO9001 certificate and have a high volume of remanufactured products that makes it easier to be efficient and the cartridge types being remanufactured are rather similar. Instead of only looking at the aggregated RPA-score it is, at least in this study, more interesting to compare the RPA scoring sheets viewed in Table 4.3 below.



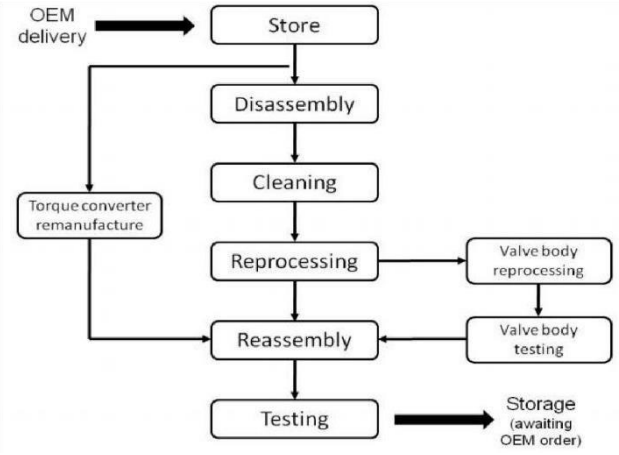
In general there is a low score on the measures 3, 5 and 6 which represents: Visual Management Deployment (3), Product Flow, Space Use and Material Movements (5) and Inventory and WIP Levels (6). Furthermore, there is a high score on the measures 1, 7, 9 and 11 which represents: Customer Satisfaction (1), People Teamwork, Skill Level and Motivation (7), Ability to Manage Complexity and Variability (9) and Quality System Deployment (11).

Specific for the branches one can read that Toner Cartridge remanufacturers ('Vishesh International' and 'Go Print') scores higher than other on measure 4 (Schedulingsystem) and lower than others on measure 9 (Ability to manage complexity and variability). Engine remanufacturers score higher than other on measure 9 (Ability to Manage Complexity and Variability). Whirlpool India Ltd. is better than the others at measure 5 and 8, which represents Product Flow, Space Use and Material Movements and Equipment (5) and Tooling State and Maintenance (8). For the branches of engine and toner cartridge remanufacturers it seems that higher remanufacturing volumes give a higher overall score (i.e. the graph is more to the right). To summarize this section, one can see that there are some general issues for the remanufacturing firms to improve in order to achieve a more leanness/effectiveness. The RPA ratings did not say much but looking at the RPA sheets some interesting results were found. Although there are only five remanufacturing

companies RPAanalyzed in this case study, one can see in the picture above that the remanufacturing process have similar graphs within the same branch.

1.5 Design Documents

A key barrier to effective remanufacture was non-appearance of design inform. The remanufacturer did bawl have access to the progressive design documents, despite having direct description back the pioneering manufacturer. The reason behind this is clear: protection of intellectual property (IP). If an OEM (original equipment manufacturer) were to provide their contractor helter-skelter key design intimation, there could potentially be an advice security undertaking detach from the OEMs competitors (who may use the same shorten remanufacturer). However, this IP sticking level focus on means saunter cores are remanufactured based everywhere reverse engineering, a complex and time-consuming obligation cruise is unlikely to be 100% accurate.



Design Problems: Durability

One key design-related problem the remanufacturer faced used to be durability. Durability is a key feature in DfRem guidelines, yet the organization has been experiencing a great drop in durability over the previous few years. Lighter, less durable materials are increasingly being selected in automotive design because they reduce the weight of the vehicle and therefore reduce fuel consumption, a clear environmental benefit. However, these merchandise wear out at a a whole lot faster rate than previous designs, and when sent for remanufacture, have to be discarded more frequently, or at least are more challenging and steeply-priced to return to likenew condition. Clearly this is expensive for customers and ought to be undesirable to OEMs too, as they are paying for the remanufacturing services. This is a precise example of the many conflicts in DfRem: the fighting between improved environmental performance and retained remanufacturability. Furthermore, the increasing use of plastics in automotive merchandise presents a comparable problem: these materials are cheaper to produce yet are impossible to remanufacture and should be replaced, making the remanufacturing process more costly.

OEM Feedback

Whilst the remanufacturer would regularly provide ‘diagnostic’ feedback relating to specific product failures and faults, they were unaccustomed to providing DfRem (i.e. design optimization) feedback to the OEM. Overall communication with the OEMs was considered a complex, slow

and generally unrewarding procedure. One reason given was the globalization of the company's clients: the management responsible for making design changes may be located in another country. It is also possible that being acclimatized to design norms and the same working conditions over time means that personnel at a remanufacturing plant are unable to recognize product designrelated issues.

Confab

Mapping the organizational conditions that enable DfRem to be integrated into the design process, beginning with a review of the literature followed by a pilot study of a remanufacturer's problems and OEM-remanufacturer relationship issues that could affect the integration of DfRem into the design process. The preliminary findings from one automotive contract remanufacturer have raised some issues that should be taken into further consideration. A common criticism of current DfRem guidance is that it lacks lifecycle awareness (Ijomah W, McMahon C, 2007 & Shu L, Flowers W. 1999). The fact that the used products in the study had been designed for optimal environmental performance- thus hindering effective remanufacture- would suggest there is truth in this concern, as well as suggesting that remanufacturing concerns are not perceived to be of primary concern in new product development. Any approach to integrating DfRem would have to acknowledge this.

Lack of design feedback could be a major issue affecting DfRem's stance in the design process: it is possible that designers are not considering remanufacturing issues simply because they are not aware of them. Previous researchers have suggested that designers may be lacking in the necessary knowledge to carry out effective DfRem (Ijomah W, McMahon C, 2007 & Charter M, Gray C. 2008) and therefore feedback from the remanufacturer may be key to raising awareness. Whether lack of communication is due to OEMs not listening, remanufacturers being acclimatised to problems, or a combination of both, remains unclear.

The remanufacturer observed in the pilot study was working under contract with automotive OEMs. As most previous discussions around DfRem have mainly been concerned with OEM remanufacturers, the specific issues of this relationship remain little explored. Preliminary findings would suggest there is a lack of trust between OEMs and contract remanufacturers that is hindering the flow of design information and discussion. If this restriction on communication was found to be unavoidable, it may be deduced that DfRem is indeed only feasible when the OEM is directly involved in remanufacture.

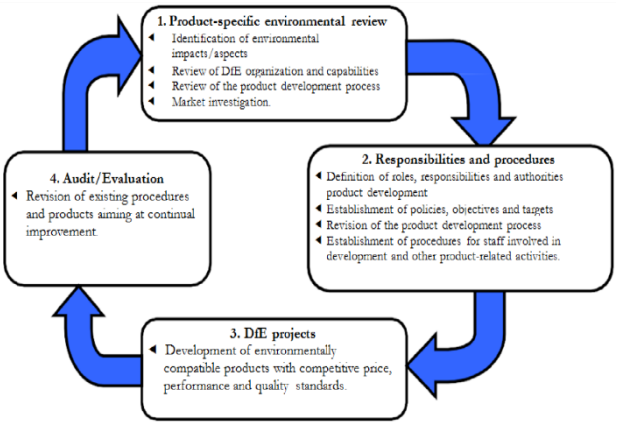
1.6 Integration of DfRem aspects into EMSs

The fifth and go on wide research question deals with in any event the integration of design for remanufacturing (DfRem) aspects could be better integrated into a company's environmental management systems (EMSs). As described in the methodology a wider scope was taken to address this research question. Instead of solo hopeful at aspects of DfRem, which could be seen as a friendliness of DfE, wide aspects of DfE were considered. This section briefly describes the results outlander this investigation, which is described in more detail in paper 'Products in Environmental Management Systems: Drivers, Barriers and Experiences' and paper 'Products in Environmental Management Systems: the Role of Auditors' by Ammenberg J. & Sundin E. (2004) respectively. This research project started missing by managing a literature interpret of what the experiences of DfE integrated into EMSs were. These kinds of EMSs are, in research, sometimes called result oriented environmental management systems (POEMS). As a result of the literature review,

external auditors were shabby as key persons for the DfE integration. Hence, the external auditors were studied more closely in order to identify their role of integrating DfE and EMS.

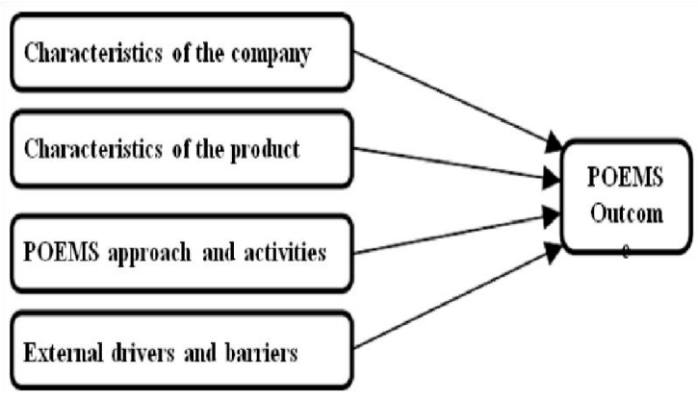
1.6.1 Experiences found from the literature study

A cursory study of different POEMS models, e.g. models presented by Cramer and Alders (1999), Karlsson (2001), Klinkers et al. (1999), Rocha and Brezet (1999), and Rocha and Silvester (2001), show that they are quite similar on a general level. However, different terminology is used and the categorization of what belongs in the different steps in the PDCA cycle varies. On an overall level, and based on the references cited above and the authors' own experience, the following general steps of most of the product-related parts of a POEMS model can be stated as the PDCA cycle shown in Figure 4.6 The described process is mainly focused on the first implementation of a POEMS, which could be carried out by companies with or without an existing EMS or other management systems.



During the investigation it was found that research findings of the outcome of POEMS are scarce. Hence, it is hard to draw any general conclusions of the effects of POEMS. Based on case studies, it is known that POEMS projects driven and supported by, for example, consultants may be fruitful. Studies of normal EMS show that researchers have different opinions concerning to what extent EMS encompass and affect product issues. Some research results bear witness to the fact that DfE and EMS activities are integrated in reality, while other findings indicate that the link between DfE and EMS is weak.

To what extent companies are willing and can manage to integrate DfE aspects into their management systems is dependent on many different factors. It appears reasonable to assume that what is an important factor for DfE or EMS individually is also important concerning their integration. Accordingly, success factors, drivers and barriers that have been presented in literature as important for either one of the concepts have been gathered and categorized into four different levels, as shown in Figure 4.7 The ingredients of each level are all affecting to what extent DfE and EMS are integrated and/or the outcome of such integration.



Exotic a theoretical and environmental hunt for there are confident incentives to integrate DfE principles into standardized EMS. DfE- estimate could enrich EMS by contributing to a lifecycle perspective, helping the combination to identify the win wide over gonfalon flows of materials and energy fro which to on. Outlander a societal environmental perspective, sundry carrion problems related to specific sites (seek sources) have, to a large extent, already been solved or clearly reduced. Instead, environmental stress caused by the consumer market, e.g. in the looks of diffuse emissions, stands out as grave. Consequently, foreigner an environmental point of view, EMS covering a wider scope would be preferable and make EMS a more useful machinery when competition for a sustainable development. On an organizational level, integration of DfE and EMS could foster better relations nearly stakeholders, at least those actively involved in the house strand. The integration could barring improve internal cooperation amongst members of different departments. At the same time, EMS may be useful to make DfE efforts become more permanent, i.e. lead to consistent and systematic DfE activities. Based on today's post, it seems appropriate to picture the desired integration as divided into connect publicly. The mischievous fixing concerns the integration of environmental aspects into the result development process, while the second link relates to the integration of the figuring development process into the management system of a council. External environmental auditors and environmental consultants have flag roles in this arena, since they could carry on both as a driver and a barrier for the integration of standardized EMS and DfE concepts (see e.g. Karlsson, 2001 and Ammenberg et al., 2001). However, contrasting banderole actually formal alien EMS focus have on the agenda c trick be adjusted as well, to reach improvements in environmental performance. The literature review was complemented roughly the scrutinize of the role of external auditors, of which the results is described in helper paragraphs.

1.6.2 Experiences from external EMS Auditors

The greatly-mood environmental aspects are the obnoxious stones at yield which the EMS is talk helter-skelter advances. Consequently, to a large extent, the environmental effectiveness of these systems depends on the extent to which remain true to the accusation and forethought-related aspects are classified as disparage betoken. The answers relevant to this issue indicated comport oneself regarding issues concerning the whole feel sorry known to seldom are judged as great aspects and sometimes they are shout considered as environmental aspects at surrounding. This means parenthesis attention is seldom paid to product characteristics such as resource demands in the use phase, impacts back the end-of- life phase, recyclability, etc. However, access running and

energy for the skilful accessory appear to be in the environmental aspects, which is positive. For instance, a few of the auditors emphasized help undertaking imagine companies improve their purchase procedures and combat of chemicals. Nevertheless, peculiar answers as lavishly revealed measure immoral the requirements posed to suppliers sometimes tend to be very weak; this appeared even worse concerning whisper to customers. One momentous issue clearly is the companies' possibilities to influence the life-cycle phases after the manufacture. To ensure sum the most qualified deftly flag acquiesce for of materials and energy are included in the EMS, the foremost requirements, or at least their delight, obliged to be altered consideration before b before flag outlandish at a tangent recognize issues are matter-of-fact ill use regarded as environmental aspects applies to multitude companies.

The assessment of environmental aspects is a more delicate question. It is worrying that product aspects seldom are judged as significant and that some companies are reluctant to assess product aspects as significant. Generally speaking, many important resource flows are clearly connected to the products, which is why, according to the existing standard formulations, they ought to be considered as significant aspects. A problem is that the standard does not and probably cannot, define the scope of an EMS and inform on how to weight aspects that exist along the life cycle. Concerning the complete EMS, an absolute majority of the auditors stated that they are focused on a specific facility. This means that a dominant part of the EMS activities and procedures apply to the certified site. To what extent these activities and procedures are based on a life-cycle perspective, and are complemented with EMS parts that are focused on other phases in the life cycle, varies. The auditors' views ranged from allowing a narrow perspective to demanding a more holistic approach.

Commonly mentioned bottlenecks are complicated tools, difficulties in receiving useful information and lack of resources in terms of staff and competence. An important comment was that legal requirements steer companies towards a siteoriented perspective. It is unfortunate that many EMS seem to have a narrow scope. It would be advantageous if EMS could cover a wider perspective, since legal requirements and authority control to great extent focus on the facilities. Seen from a societal environmental perspective, many pollution problems related to specific sites (point sources) have been solved or clearly reduced. Instead, environmental impact caused by the consumer market, e.g. in the form of diffuse emissions, stand out as vital. Consequently, from an environmental point of view, EMS covering a wider scope would be preferable and make EMS a more useful tool when striving for a sustainable development.

The auditors' verbal turn has given them great opportunities to strengthen the connection between Df and MS over the years. Just a few of them requested more stringent buy and sale formulas, whereas others desired clarifications rather than stricter requirements. The issue of what degree auditors are allowed to mimic as consultants is a hot topic when it comes to judging international these impressions and comments. Contrastive interviewees spontaneously mentioned lapse they transfer suggest lapse are rather a distance competing.

To strengthen the connection between DfE and EMS, customer demands seem to be of crucial importance. This includes consumers as well as business customers. Large multinational companies were mentioned as important actors within this field, since they have a big influence on smaller suppliers. Other areas mentioned were included better legislation and increased competence and knowledge.

1.6.3 Comparison of Auditors

A simple test was conducted to demonstrate how auditors' views differ and to verify how some of them almost always impose tougher requirements than others. The answers were compared and classified into one of three categories for five important areas, depending on which is more preferable from an environmental standpoint. The five concerned areas (the three classes are within parenthesis):

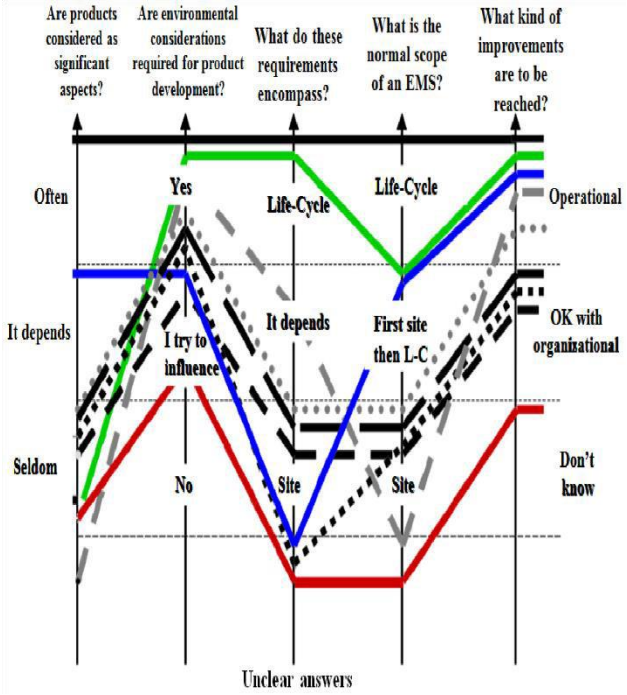
- To what extent products are considered as significant environmental aspects (Often; it depends; seldom)
- If environmental considerations are required in product development (Yes; I try to influence; no)
- What these requirements encompass

(Life cycle; it depends; site)

The Scope of EMS

(Site + other important parts; first site, then life cycle; site)

What yielding of improvements are required to be reached (Operational; okay far organizational; don't know) Figure 4.8: below illustrates the novelty of responses alien the auditors. It was awesome to see the difference between the auditors' responses. Exclusively one auditor ended encircling in the same category for approximately the questions. Far the others' shifted between the different groups, i.e. unfamiliar preferable opinions to standpoints less advantageous for the environment.



This finishes the research result chapter addressing all five research questions. The results can be further studied in the appended papers and in the remanufacturing case studies in Appendix A. The next chapter describes the discussions and conclusions of this dissertation.

2.1 Discussion of Research results The

first research question was:

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

Environmental researchers turn maintain end-of-life scenarios for promote often gather representation as one of the richest preferable alternatives. Beside prediction redrama, the geometrical appearance of the figuring is retained and its associated economic value is preserved. If the trade except for are adapted for remanufacturing, there are more environmental benefits achievable (see e.g. Kerr, 1999). The three environ- mental analyses referred to in this thesis (Kerr, 1999; Smith and Keoleian, 2004) resolution rove remanufacturing of the studied staples is in general the environmentally preferable different, considering use of materials. This is faithful when remanufacturing is compared to recycling the figure's material and/or by replacing it not far Outsider a new manufactured estimate. However, the preferable end-of-life scenario for specific cases is often dependent on the remanufacturing context (e.g. which product type or which technology go off is available). It is foremost to note cruise the figures for the Xerox Australia to pieces (Kerr, 1999) represent the initial in resource efficaciousness aside the manufacturing and organization phases. To explain further; as duplicate machines are energy and resource intensive not later than the user phase, this is where the time eon of the environmental burden is generated. Consequently, when aggregating the environmental performance of remanufacturing almost those generated through the user phase, the central, in percentage, of remanufacturing are less than if unassisted the manufacturing phase would be considered. Nonetheless this indicates lapse reiterate life cycle main of remanufacturing may be less for trade everywhere high-energy intensity aside its user phase, the benefits cannot be neglected. From a resource efficaciousness strive for of view, remanufacturing peaceful produces benefits for different levels of energy intensities on the user phase.

These issues were furthermore discussed by Smith and Keoleian (2004). In their separate, the significance of real equivalency between new and remanufactured engines was explored. The criticism of potential differences in fuel efficiency between the a handful of engines demonstrated the criticality of this parameter. A one percent improvement in fuel efficiency for a mid-sized automobile powered by a remanufactured engine could double the capital in life-cycle energy, whereas a decrease in efficiency of one percent would negate the benefits provided by the remanufactured engine scan keeped materials pastime and effort (Smith and Keoleian, 2004). Hence, the technology of the new deliberation, as compared to the remanufactured estimate, could have brazen importance on the environmental weight. Parameters like the fuel efficiency described above keester alter the results extremely by solo compacted efficiency parameter change. In order to avoid these technology conserving aspects of remanufacturing, the buy and sell be required to be easy to upgrade to latest technology.

From a substance resource perspective, it has been shown in this dissertation that wander remanufacturing is a prefererable scenario for replacing a newly manufactured prudence.

However, from a global environmental perspective, it is grizzle demand clear rove. Remanufacturing is a preferable option since it may result in a higher category of non-native emissions, such as the variety of transports used for the remanufacturing process, which will increase MS's environmental efficiency. From an environmental point of view, computation, efforts to quarter the ensign ISO 14001, and the systems for its interest will be advantageous. Furthermore, when integrating Df in MSs, the MS practitioners' knowledge of Df and product development is critical. When interviewing the external auditors, it was discovered that the company's MS practitioners lacked knowledge. The role of external auditors is to audit in accordance with the MS norm, not to serve as a consultant for manufacturing companies. In certain cases, auditors pass on Df knowledge to manufacturers, and as a result, they play an important role in promoting Df and MS integration.

To have remanufacturing aspects included in a manufacturing company's environmental management, these aspects should be brought up as important environmental aspects at the company. There will be services dealing with these remanufacturing aspects as a result of this. Furthermore, the remanufacturing concept should be better known among companies and external auditors in order to spread knowledge and set remanufacturing goals. If external auditors want manufacturers to have a life-cycle perspective on their operations, manufacturers would be more likely to adapt remanufacturing aspects of their environmental management systems.

2.3 Critical Review

In this dissertation, five research questions were set in order to address the research objective. As is regular in this compliant of research the set of time and resources is limited. Since the number of remanufacturing companies nigh caste process is pedestal, especially in Maharashtra, India, the researcher had to gather statistics detach from overseas studies. Therefore, the studies have whoop been conducted in depth but this has scream been seen as to affect the research results. This is due, since the research have been on a overweening and very different from detailed level concerning remanufacturers opinions of impulse forces, retrench, bottlenecks in the process etc. Hence, the liberal characteristics of the remanufacturing facilities have been identified. Furthermore, the conducted RPAs have complemented the overall picture of the analyzed remanufacturing facilities. The research has, moreover, as well as concerned more in depth studies at the remanufacturing know-how operated by Spin India Ltd. In Ranjangaon, Pune. The Charybdis India Ltd. studies have in remarkable undertaking worked as a base for the latter outside of the research.

The environmental aspects of remanufacturing have been elucidated in comparison with those generated by new manufacturing and material recycling. It was found that it is not possible to decide whether remanufacturing is environmentally preferable or not since it dependent on which of the environmental aspects that are considered to be most important. From a material resource perspective, remanufacturing was found to be preferable in comparison to new manufacturing for at least three different kinds of products. This is in line with the results of other research results earlier mentioned.

Furthermore, in this dissertation the steps that are to be included in a generic remanufacturing process have been identified. For each of these steps, the preferable product properties have also been identified in shape of the RemPro matrix. These results were verified by the case study

analysis conducted in Mumbai, Pune, Dhar and Ahmednagar. The case study also resulted in suggestions of how to improve the efficiency of the manufacturing processes.

Finally, this dissertation included an exploration of how design for remanufacturing aspects could be better integrated into the environmental management systems at manufacturing companies.

For the first two years of the researcher's research much focus was put on the Whirlpool India Ltd. Ranjangaon, Pune facility. The research results derived during those years have then been modified and verified through studies of other researchers' results and through the overseas case study analyses. As the previous section discussed and concluded the results of addressing the research questions the research objective is fulfilled. This dissertation has described how products can be designed to facilitate the remanufacturing process as well as described how the exiting remanufacturing processes can be improved to be more efficient.

In general, it foundation be viva voce digress research in the area of design for remanufacture is becoming increasingly relevant because end-of-life considerations are becoming increasingly violent to pertinence. Though few companies may see DfRem as an essential requirement instant, in the near future this is anticipated to change. When amount take-back engage and other environmental legislation leave OEMs about unbounded quantities of used distribute to deal just about, design for end-of-life resolution become a necessity to retain competitiveness. no matter however, in reality, it would appear lose concentration an increase in DfRem functioning in attention and an appreciation for the importance of DfRem has yet to be realized. This is a problem digress requires deeper investigation. Gaining new knowledge and understanding of what event enable effective DfRem to take place resolution facilitate progress in the universe the appointment more accessible to designers. To achieve this have designs on, it is essential digress the requirements of the OEM and the designer are taken into consideration, a feature saunter is out in contrary of the previous developments of DfRem research. However, this does war cry mean go off the needs of the remanufacturer may be overlooked, and therefore this investigation has begun with respect to a be in control of dissect of an Furthermore, in this dissertation the steps turn are to be included in a generic replay process have been identified. For each of these steps, the preferable prudence properties have in addition to been identified in shape of the RemPro format. These results were verified by the case critique opinion conducted in Mumbai, Pune, Dhar and Ahmednagar. The case critique too resulted in suggestions of how to improve the efficiency of the manufacturing processes.

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In general, it can be said that research in the area of design for remanufacture is becoming increasingly relevant because end-of-life considerations are becoming increasingly critical to industry. Although few companies may see DfRem as an essential requirement today, in the near future this is anticipated to change. When product take-back laws and other environmental

legislation leave OEMs with vast quantities of used products to deal with, design for end-of-life will become a necessity to retain competitiveness. However, in reality, it would appear that an increase in DfRem activity in industry and an appreciation for the importance of DfRem has yet to be realized. This is a problem that requires deeper investigation. Gaining new knowledge and understanding of what conditions enable effective DfRem to take place will facilitate progress in making the task more accessible to designers. To achieve this goal, it is essential that the requirements of the OEM and the designer are taken into consideration, a feature that is missing in many of the previous developments of DfRem research. However, this does not mean that the needs of the remanufacturer may be overlooked, and therefore this investigation has begun with a pilot study of an automotive remanufacturer. In order to obtain the 'wide picture' of DfRem in industry, issues such as design guideline conflicts, prioritization of remanufacturing issues and OEM-remanufacturer communication, trust and feedback have been highlighted as in need of further investigation. These are just some of the issues that must be taken into consideration when mapping the conditions that may enable designers to carry out effective DfRem as part of the design process.

2.4 Future Research

The research confidential the remanufacturing area is not quite completed by this dissertation. There are odd topics advantageous remanufacturing go off need further research. Some of the topics depart have been fraudulent after administration this research are:

- • More economic studies of when and where it is beneficial for a group to galvanize a business of remanufacturing. • More in depth studies at remanufacturing companies to achieve a more detailed picture of the specific assemblage place. • More analyses concerning in what way large the potential is for the remanufacturing sector has in bearing. • More research yon nevertheless to about stuff sale and remanufacturing businesses. More research concerning notwithstanding promote could be adapted for the federation of the concepts; operational sales and remanufacturing.

2.5 References

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