5. Benefits of Remanufacturing: An Analysis

In order to primarily address the issue of cost that the customers consider while choosing between the remanufactured and their counterpart product, it was decided to explore the issue by analyzing the cases of DMW of Indian Railways, Timken India and Inkguide and the hypothesis addressed is:

\[ H_{03}: \text{Cost incurred for a remanufactured product is less than cost incurred for a new counterpart product.} \]

As part of this effort, existing literature in the Indian and USA contexts were explored in detail and studied.

Coefficient of Correlation between various factors and T-test were conducted to arrive at the conclusion.

5.1 Introduction

Remanufacturing is a sizzling business prospect worldwide and the business of e-waste is the most beneficial and therefore successful outcome (Guide and Li, 2010; Cruz and Mulholland, 2000). India is the second most populated country in the world and the need of remanufacturing is identified a decade and a half ago in India. According to leading Indian manufacturers, Indian industries, though have made a slow start, are yet to come to terms with it and thus the industry is still in its early life. In fact, keeping environmental and cost issues in mind, firms in the cartridge manufacturing have started remanufacturing in a big way.
5.2 Scope of Remanufacturing in Indian Market

Today remanufacturing is a $35 billion industry, which represent nearly 30 percent of the $115 billion worth printer cartridges market globally. However, the Indian remanufacturing industry continues to play a secondary role and even after more than a decade of existence, it is yet to categorize itself and chalk out powerful strategies. The secondary role played by the Indian remanufacturing industry is mainly due to lack of associations and negative end user opinions. According to Indian Cartridge Remanufacturers & Recyclers Association (ICRRA), only less than 10 percent remanufactured and refilled inkjet cartridges, laser toners were sold, and among these, only 20 percent cartridges were remanufactured in India. Cartridge making firms in India have largely been into refilling than remanufacturing (The Channel Business, 2012).

The cost is a key deciding factor, as people are unwilling to pay 75 percent of the price of the Original product (Atasu, 2010). Aggressive tactics for remanufacturing in India have also been formulated by Static Control Components (SCC). The company produces some 13,000 different parts including drums, ink, casings and chips for 1,200 different toners and cartridges (Geetha, 2011). According to International Director Sales of India SCC, the Indian market has very tough conditions and is under developed, but has enormous potential and this market will be very important in the future with firms investing a lot of time, energy and money into it. Timken is an international leader in friction management technologies and provides one of the most complete offerings of antifriction bearings in the industry and also offers remanufacturing options for bearings and related equipment’s. Remanufacture and repair of qualified components is
frequently an economical alternative to replacing it with new ones (Alexander, 2009).

5.2.1 Views of Regulatory Authorities in India on Remanufacturing Issues

The proposal of free trading of remanufacturing products in view of profitability and environmental protection is driven by the USA in the last World Trade Organization (WTO) meeting at Geneva. However, such an important issue did not get any importance during the recently concluded meet. It is very unfortunate that remanufactured goods have not been defined in the Foreign Trade Policy (FTP) in India. Under Para 2.17 of FTP, import of remanufactured goods are allowed against the license (MFDR, 2012). The Article ‘Ministerial Decision on Trade in Remanufactured Goods’ also shows the lack of awareness of Government authorities about policy making related to remanufactured products (IWTO, 2009). The article clearly demonstrates the approach filled with full of negativity about remanufacturing of products. It may be noted here that India is losing huge assets and employment opportunities due to such approaches of regulatory authorities.

Today, top industries like Caterpillar, GE, and Timken etc. are engaged in remanufacturing of products. Automotive parts, cartridges, electronics, medical devices etc. are major industries in this sector, which are trading globally. They have already crossed $100 billion business in remanufacturing and have formed production facilities in Asia, Africa, Europe and Latin America, in addition to the biggest market, the US. Developing countries think that the trade of remanufacturing product means transport of waste from developed countries to them or in other words, it is the easy way of shifting of environmental and safety burden from developed countries to developing countries.
India permitted imports of second-hand assets goods by the end users without requiring an import license but for importing the remanufactured products, import license is necessary from Indian charted engineers. Whereas India’s official Foreign Trade Policy (FTP) issued in the last October 2011 treats remanufactured goods the same as second-hand products and has not made any differentiation among remanufactured, refurbished, reconditioned and second-hand goods (FTB, 2011).

5.2.2 APRA on Remanufacturing Issues in India

The Automotive Parts Remanufacturers Association (APRA) is one of the top associations working for automotive remanufacturing sectors. Thousands of firms involved in remanufacturing are members of APRA. President of APRA has advised the Indian Government to allow trade in remanufactured products on the same basis with new manufactured products (Bill Gager, 2011). APRA president has also stated that the refusal of remanufactured products puts India in the position of supporting anti-environmental policies and not providing cost-effective alternatives for Indian consumers and industries. The Indian Government should move quickly to change the international import rules on trade in remanufactured products. India, being the second most populated country in the world with 17% of world population, should accept trade in remanufactured products to promote the establishment and growth of a remanufacturing industry. In the event of the Indian government allowing the remanufacturing sector, near about 5, 00,000 jobs will also be created as in the U.S. market (Gager, 2011).
5.2.3 Efforts of the Associated Chambers of Commerce and Industry of India on Remanufacturing

The Associated Chambers of Commerce and Industry of India (ASSOCHAM) had conducted a national seminar on ‘Remanufacturing’ in 2009 and have concluded certain remarkable points for achieving sustainable growth. ASSOCHAM has stated that the Government of India should allow remanufactured products without import license. Original Equipment Manufacturers (OEMs) are having a huge market share in India and only they should be allowed as remanufacturers in initial stage. Due to the fear of product cannibalization of new products, many OEMs are not entering into remanufacturing business (Jindal, 2009). Landfills of EOL products are harmful to soil and water degradation and other harmful effects and hence remanufacturing is the true solution to reduce waste for sustainable growth. For consumer, remanufactured products are an excellent option, because price of remanufactured product is usually less by 30 to 35% of new products. As per the definition, remanufactured products have to give the same performance parameters as per the customer expectations with the same warranties as new products have. The Chamber has also suggested that the Indian Government should insist that for each remanufactured product imported, the party should export a corresponding EOL product.

5.3 Remanufacturing at DMW

Indian Railways started Diesel Loco Modernization Works (DMW) at district Patiala, India in 1981. Due to huge amount of EOL products, DMW started remanufacturing of those EOL parts in 1989. Spare parts like Microprocessor Control System, AC-DC power transmission, Fuel Efficient Engine Kits, Roller Bearing Suspension System, Traction Motors, Crankshaft,
revolving chair, fan, and large size sliding windows are remanufactured every year (See fig. 5.1). Thousands of parts are remanufactured by DMW, which saves huge amount of energy, material and capital cost. This case study evaluates the need of remanufactured locos and its benefits. The Indian railways are doing well in the remanufacturing sector and Government is getting huge benefits then the question arises as to why Government policies are not supportive to remanufacturing import policies. This case study is useful as a guide to many industries in India to start the production of remanufactured product for GGS.

5.4 Cost Associated with Remanufactured Locos

![Figure 5.1: Values of Locos Remanufactured](image)

Details of remanufacturing data from the year 2000 to 2011 have been shown in fig 5.1. In the year 2000-01, 64 locos had been remanufactured and cost associated during this year was Rs. 41.8 Crores. Remanufacturing cost per locos was around Rs. 0.6531 Crores in 2000-01 and this cost was little bit steady between the years 2000 to 2005. Cost of remanufactured
locos was seen increasing from 2006 to 2011 and finally it moved up to Rs. 1.4 Crores (see the fig. 5.2).

![Figure 5.2: Cost of Remanufactured Local per unit](image)

Table 5.1 shows the annual growth in percentage for remanufactured locos from the year 2000 to 2011.

<table>
<thead>
<tr>
<th>Year</th>
<th>No. of Locos Remanufactured</th>
<th>Annual Growth in %</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000-01</td>
<td>64</td>
<td>NA</td>
</tr>
<tr>
<td>2001-02</td>
<td>63</td>
<td>-1.15</td>
</tr>
<tr>
<td>2002-03</td>
<td>73</td>
<td>15.76</td>
</tr>
<tr>
<td>2003-04</td>
<td>73</td>
<td>0</td>
</tr>
<tr>
<td>2004-05</td>
<td>74</td>
<td>1.15</td>
</tr>
<tr>
<td>2005-06</td>
<td>73</td>
<td>-1.15</td>
</tr>
<tr>
<td>2006-07</td>
<td>86</td>
<td>17.8</td>
</tr>
<tr>
<td>2007-08</td>
<td>102</td>
<td>18.6</td>
</tr>
<tr>
<td>2008-09</td>
<td>108</td>
<td>5.88</td>
</tr>
<tr>
<td>2009-10</td>
<td>112</td>
<td>3.7</td>
</tr>
<tr>
<td>2010-11</td>
<td>110</td>
<td>-1.7</td>
</tr>
</tbody>
</table>
The number of Remanufactured locos has been increasing consistently and finally it has reached around to 110 locos. Future demands of remanufactured locos are seen increasing and in the coming years, it is expected to cross 200. Hence the DMW has to make a plan according to the future demand. In 2007-08, growth percentage of remanufactured locos was seen increasing up to 18.6 and in 2011 the growth was little bit negative. Remanufactured locos are giving constantly good results on the field and Indian Railways are saving huge amount of energy, material and capital investment for GGS.

### 5.5 Cost saving due to Remanufactured Locos

For remanufacturing of locos, subassemblies like Engine Blocks, Traction Motor Magnet Frame, Converted Magnet Frames, Locos under Frame Weight and Bogie Frame Weight go through vigorous remanufacturing operations to achieve the quality of subassemblies ‘as good as’ the new one.

#### Table 5.2: Cost Saving due to Remanufacturing in %

<table>
<thead>
<tr>
<th>Description</th>
<th>Weight in tons</th>
<th>Cost of New Unit (Rs. in Crores)</th>
<th>Cost of Remanufactured Units (Rs. in Crores)</th>
<th>Cost Saving due to Remanufacturing in %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engine Block</td>
<td>5.5</td>
<td>0.15</td>
<td>0.045</td>
<td>70</td>
</tr>
<tr>
<td>Traction Motor Magnet Frame</td>
<td>1.25</td>
<td>0.015</td>
<td>0.005</td>
<td>67</td>
</tr>
<tr>
<td>Converted Magnet Frame</td>
<td>1.25</td>
<td>0.015</td>
<td>0.005</td>
<td>67</td>
</tr>
<tr>
<td>Loco under Frame Weight</td>
<td>20</td>
<td>0.200</td>
<td>0.020</td>
<td>90</td>
</tr>
<tr>
<td>Bogie Frame Weight</td>
<td>3.5</td>
<td>0.050</td>
<td>0.005</td>
<td>90</td>
</tr>
</tbody>
</table>

Table 5.2 explains about the cost of new unit and cost of remanufactured unit. Traction Motor Magnet Frame and Converted Magnet Frame require Rs. 0.015 in Crores for new units but for remanufactured
operation, the cost required is 67\% less than the cost required for new one. Engine block also required Rs. 0.15 in crores for a new unit, but the remanufacturing operation saves around 70\% cost. Parts like Loco under Frame Weight, Bogie Frame Weight saves 90\% of costs due to remanufacturing operation and this is a remarkable saving in cost. From 2000 to 2011, total locos remanufactured are 938 and the total cost required for remanufactured operation is 807.42 crores. From table 5.2, it is clear that the average cost saved due to remanufacturing is around 75\% of new product. Due to remanufacturing, DMW saved around Rs. 2422 Crores from the year 2000 to 2011. This cost saving due to remanufacturing plays an important role in the Indian Railway Industry and this is also considered a very important step towards green growth and sustainability so null hypothesis formulated $H_{03}$: Cost incurred for a remanufactured product is less than cost incurred for a new counterpart product has been accepted.

5.6 Remanufacturing at Timken

Timken India sold different types of bearings in the market as per the customers’ need. Company also provides the repair services to clients and it creates huge secondary market for business. Many top companies in the world purchases high quality bearings from Timken with maintenance agreements. At the EOL of Bearings, Timken offers remanufactured bearings with repair service. Quality of remanufactured bearing is near to the quality of new bearing and remanufacturing operation saves material, energy and capital investment of the company. Sustainable product development is also a very important key factor to protect environmental pollution related issues (Brezet and van Hemel, 1997). In all aspects, remanufacturing products are helpful to the OEMs as well as clients.
Timken provides a wide range of comprehensive bearing refurbishing/remanufacturing and maintenance services. With these services, bearings could be brought to almost its new condition. Timken provides repair service, under which customers choose category of service as per the monitory benefits. The bearing refurbishing/remanufacturing services help to extend the life of bearings and provide economical functionality. Timken remanufactures tapered roller bearings, spherical roller bearings, cylindrical roller bearings, ball bearings, thrust bearings and so on. It is always difficult to decide as to when the companies may go for the remanufacturing option. Timken suggests few signs when a product goes through inspection. For example, if the bearing life is near to the suggested life expectancy and operating temperature exceeds 200 °F due to vibration, then remanufacturing is the most suitable option for repair.

5.7 Timken Repair Section

Many top brand clients of Timken industries have signed repair contract with Timken. In the repair section, Timken offers its customers various options such as recertify, reclaim, reconditioning and remanufacturing facilities and they can choose the repair option as per their requirements (Alexander, 2009).

A. Recertify: This is the certification of a bearing for service from Timken and is normally valid for an unused product with an outdated shelf life.

B. Reconditioning: This activity involves polishing, honing, tumbling of bearings for removal of minor surface defects. These defects are caused due to rust and corrosion. Reconditioning as an activity is useful to increase the performance and life of bearings.
C. Remanufacturing: This process is the most demanded service by customers because it brings back the defective bearings near to the quality of new bearings. In this process, grinding and hard turning operations are used for removal of aggressive surface damage. Remanufacturing process also replaces the unreppaired part by new components.

5.8 Potential Life Due to Repair

Figure 5.3 shows the bearing life remaining and time in service. Bearing life remaining is inversely proportional to time in service (Gupta, 2009). Theoretical bearing life is seen decreasing due to corrosion and contamination. Regular maintenance of bearing is necessary to extend the life of bearing. If repair is not done in time, then life of bearing reduces drastically. Potential life of bearing is increasing due to regular repair and maintenance of bearing (as shown in figure. 5.3). Regular repair will increase the potential life of bearing and reduces the idle time.

Figure 5.3: Potential Life of Bearing with Repair
5.9 Remanufacturing of Bearings at Timken

Timken provides a wide range of comprehensive bearing refurbishing/remanufacturing and maintenance services. With these services, bearings can be brought to almost its new condition. Timken provides repair service, under which customers choose category of service as per the monitory benefits (Alexander, 2009). The bearing refurbishing/remanufacturing services help to extend the life of bearings and provide economical functionality. Timken remanufactures tapered roller bearings, spherical roller bearings, cylindrical roller bearings, ball bearings, thrust bearings and so on (see the figure 5.4).

Figure 5.4: Remanufacturing of Bearings at Timken

It is always difficult to decide as to when the companies may go for remanufacturing option. Timken suggests few signs when a product goes through inspection. If the bearing life is near to the suggested life expectancy and operating temperature exceeds 200 °F due to vibration,
then remanufacturing is the most suitable option for repair (Alexander, 2009).

5.10 Element of Customer Expectation

Under its repair section, Timken offers recertify reclaim, reconditioning & remanufacturing services. Most of the clients are interested in remanufacturing of bearings and chocks due to its increased potential life. Users and clients expect the following elements from Timken (Alexander, 2009).

A. Minimization of Capital Cost: Operation of plant and machinery with lowest cycle cost of component.

B. Maximization of Uptime and Productivity: The effort is to minimize the equipment delays and unproductive time with planned maintenance.

C. Improvement of Product Quality: Client expects the improvement of quality of product by up gradation and preventive maintenance.

D. Maintenance of Minimum Inventory of Component: Clients always expects to keep the optimum inventory level to control capital investment at a minimum level.

5.11 Remanufacturing Stages at Timken

Once EOL product is returned to repair centre, company selects the bearings for remanufacturing operations. Remanufacturing operations are shown in fig.5.5 Disassembly of EOL product and inspection of each part is necessary before polishing, grinding process etc. Before disassembly process, recording of the bearing information and actual internal clearances is necessary. Then it is to complete the disassembly and tag it with unique identifiers.
Comprehensive inspection of all the bearing components was performed and findings were recorded. The initial inspection includes looking for major problems or damage, such as fractures, major bluing due to heat damage etc. These are indicators to show that the bearing may not be required for repair. Damaged parts also are examined to determine the scope of work required to return them to remanufacturing operations.

Polishing and grinding is a very important operation. If damaged part is irreparable, then new part is used in the remanufacturing process. Heating is necessary to reset the metallurgical aspects up to mark. Resetting of clearance is also one of the important challenges during the remanufacturing operation. Finally remanufactured bearing is assembled and tested for quality.

5.12 Benefits of Remanufacturing

Quality of remanufactured bearing is near to the quality of new bearing and remanufacturing operation saves material, energy and capital investment of company. Sustainable product development is also a very important key factor to protect environmental pollution related issues (O'Brien, 1999). In all aspects, remanufacturing products are helpful to the OEMs as well as clients. Fig. 5.6 shows the failure rate of remanufactured
bearings. Initially probability of damage during wearing-in is more and after initial period, bearings are working constantly smooth. Remanufactured bearings have failure rate more in initial phase and failure is more at the EOL of bearings due to fatigue. Reliability of remanufactured bearing is same as that of new bearings.

![Image](image)

**Figure 5.6: Likelihood of Premature Bearing Damage**

Few more case studies of top client companies in India were explored to study the remanufacturing services in detail. Case studies of companies like Essar Steel Hot Strip Mill, Lafarge Cement of India, Tinplate Company of India & Usha Martin were analyzed for understanding the benefits of remanufacturing.

### 5.13 Cost Savings & Productivity Enhancement due Remanufacturing

Essar Steel Hot Strip Mill (ESHSM), Lafarge Cement, Tinplate India and Usha Martin are the clients of Timken India Industry. Prices of the new bearings and chocks are shown in Table 5.3. After the EOL of these bearings and Chocks, client companies decided to purchase new bearings from Timken India Ltd. Timken advised ESHSM to choose the remanufacturing as a repair
option because bearing removal from mandrel needs gas cutting operation, which may damage the costly mandrel.

Table 5.3: Remanufacturing Service Offered by Timken

<table>
<thead>
<tr>
<th>Client</th>
<th>Essar Steel Hot Strip Mill</th>
<th>Lafarge Cement</th>
<th>TATA Steel Company of India</th>
<th>Usha Martin</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Product Details</strong></td>
<td>Bearing – (M272749A)</td>
<td>Bearing – (FAG – 517680A)</td>
<td>Chock Bearing – (4 Hi Skin Pass Mill Chock)</td>
<td>Chock Bearing – (Bar Mill)</td>
</tr>
<tr>
<td><strong>Price of New Bearings/Chocks in $</strong></td>
<td>27,500</td>
<td>1,02,350</td>
<td>60,000</td>
<td>1,25,000</td>
</tr>
<tr>
<td><strong>Price of Remanufactured Bearings offered by Timken in $</strong></td>
<td>13,475</td>
<td>61,462</td>
<td>14,000</td>
<td>50,000</td>
</tr>
<tr>
<td><strong>Direct Cost Saving due to Remanufactured Bearings in $</strong></td>
<td>14,075</td>
<td>40,898</td>
<td>46,000</td>
<td>75,000</td>
</tr>
<tr>
<td><strong>Percentage of Cost Saving due to Remanufactured Bearings</strong></td>
<td>51</td>
<td>40</td>
<td>77</td>
<td>60</td>
</tr>
<tr>
<td><strong>Lead Time for new bearings in Months</strong></td>
<td>12</td>
<td>12</td>
<td>12</td>
<td>—</td>
</tr>
<tr>
<td><strong>Lead Time of Remanufactured Bearings in Months</strong></td>
<td>04</td>
<td>06</td>
<td>04</td>
<td>—</td>
</tr>
<tr>
<td><strong>Percentage of Lead Time Saving due to Remanufactured Bearings</strong></td>
<td>67</td>
<td>50</td>
<td>67</td>
<td>—</td>
</tr>
</tbody>
</table>

ESHSM chose remanufacturing option as a repair service. Timken’s design engineers designed the fixture and dismantled the bearing without damaging it. Vigorous remanufacturing operations were carried out on EOL bearings for around 16 weeks. As mentioned in Table III, bearings are remanufactured for $ 13,475 and it saves $ 14,075. This shows that the remanufacturing bearing saves 51% amount for ESHSM. Instead of selling the new bearings, Timken preferred the remanufacturing option. Timken earned more profit in remanufacturing operations. Lead-time was saved.
due to remanufacturing operation, hence productivity has increased drastically.

Lafarge Cement entered in 1999 in India through cement market. Company uses the bearing part no: - FAG – 517680A for KHD Roller Press. Table 5.3 shows that the value of new bearings is - $ 102,360, which was expensive for Lafarge Cement Company. At the EOL of these bearings company decided to go for remanufacturing option and Timken performed remanufacturing operation worth $ 61462. In this case also, it was observed that Lafarge Cement saved the amount of $ 40,898 i.e. nearly 40 % of new bearings. The lead time for new bearings is also around 12 months; remanufacturing operation reduces it to around 50%. The Tinplate Company of India (TCI) of Tata Group is the largest producer of tin plate since 1922. Table 5.3 explains the advantages of remanufacturing operation. Life of 4 Hi Skin Pass Mill Chock is 12 years and at the EOL of Product Company wanted to replace the part by new mill choke. Timken India Ltd offered the remanufacturing service for the mill choke and TCI also agreed due to huge cost cutting. Price of new mill choke is around $ 60,000 and Timken India Ltd completed the whole operation in $ 14,000.

Quality of remanufactured product is as good as new one and hence TCI saved 67% of huge cost due to remanufacturing operation. Due to remanufacturing operation 'material, cost and lead time' was saved. From an environmental protection point view also, the remanufacturing benefited resulting in sustainable product development. Remanufacturing operation saved 67% of lead time which lead to increase in the overall productivity of the system. Usha Martin is the wire rope manufacturing company at Ranchi, India. Usha Martin also preferred remanufacturing
service from Timken and the cost benefit is around 60% as shown in Table 5.3.

5.14 Actual Cost Saving due to Remanufacturing

Fig. 5.7 indicates the benefits of remanufacturing operation in three well-known companies of India. Timken India Bearings offered remanufacturing services to industries and many industries are taking benefit of these services. TCI got 77% benefits due remanufacturing operation. The amount of cost saving due to remanufacturing operation is huge. ESHSM and Lafarge Cement also saved 51% and 40% cost due to remanufacturing operation. Companies save on the cost as well as lead-time due to remanufacturing. Large amount of lead-time is saved and productivity and overall profitability of organization is increased.

Figure 5.7: Price/Cost Saving due to Remanufacturing

Fig. 5.7 indicates the benefits of remanufacturing operation in three well-known companies of India. Timken India Bearings offered remanufacturing services to industries and many industries are taking benefit of these services. TCI got 77% benefits due remanufacturing operation. The amount of cost saving due to remanufacturing operation is huge. ESHSM and
Lafarge Cement also saved 51% and 40% cost due to remanufacturing operation. Companies save on the cost as well as lead-time due to remanufacturing. Large amount of lead-time is saved and productivity and overall profitability of organization is increased.

For calculation of maximum cost saving due to remanufacturing, data of four companies was used such as ESHSM, Lafarge Cement, TCI and Usha Martin benefited due to remanufacturing operation and is as shown in Table 5.3. The average cost saving due to remanufacturing is 57% and maximum cost saving due to remanufacturing is considered 75.93 %. It is interesting to find the nearby value of cost saving due to remanufacturing.

<table>
<thead>
<tr>
<th>Average cost Saving due to Remanufacturing (x)</th>
<th>Actual cost Saving due to Remanufacturing (μ)</th>
<th>Maximum cost Saving due to Remanufacturing (μ1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>57%</td>
<td>74.88 %</td>
<td>75.93 %</td>
</tr>
</tbody>
</table>

Table 5.4: Expected Remanufactured Bearings Cost Saving

Case I,
Null Hypothesis, μx = 75.93 %
Alternative Hypothesis, μx < 75.93 %
T-test, Level of Significance (α) = 0.05, x = 57 %
Population Distribution (N) = 4
Standard Deviation (S) = 15.64 %
T = -2.4207 is less than value T = 2.353 so Null Hypothesis (μx) = 68.66 % is rejected and alternative hypothesis μx < 75.93 % has been accepted.

Case II,
Null Hypothesis, μx = 74.88 %
Alternative Hypothesis, μx < 74.88 %
T-test, Level of Significance (α) = 0.05, x = 57 %
Population Distribution (N) = 4
Standard Deviation (S) = 15.64 %
Degree of freedom = 3, T = 2.2864 is greater than -2.353 so Null Hypothesis (μx) = 74.88 % has been accepted.

On available data as shown in Table 5.4, T-test is the most feasible analysis to find out nearby value of cost saving due to remanufacturing. Null hypothesis & alternative hypothesis have been shown in the table 5.4 In Case I, value of T-test is less than -2.353 and hence null hypothesis is rejected and alternative hypothesis has been accepted. Since the maximum
cost saving due to remanufacturing value is less than 75.93 %, case II was conducted, as it is necessary to find nearby value of cost saving percentage due to remanufacturing. From case II, it is seen that the expected cost saving due to remanufacturing is 74.88 %. In the T-test, it has been proved that null hypothesis is accepted and maximum cost saving due to remanufacturing value is 74.88 % (see the table 5.4). Due to the remanufacturing initiative taken by Timken, bearings in the Indian market saved cost up to around 74.88 % and this is really a significant cost saving so null hypothesis formulated $H_{03}$: Cost incurred for a remanufactured product is less than cost incurred for a new counterpart product has been accepted.

5.15 Actual Lead Time Saving due to Remanufacturing

Table 5.5: Actual Lead Time Saving due to Remanufacturing

<table>
<thead>
<tr>
<th>Average Lead Time Saving due to Remanufacturing (%)</th>
<th>Actual Lead Time Saving due to Remanufacturing ($\mu$)</th>
<th>Maximum Lead Time Saving due to Remanufacturing ($\mu_1$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>61.33%</td>
<td>77.80%</td>
<td>78.00%</td>
</tr>
</tbody>
</table>

Case I,
Null Hypothesis, $\mu_0 = 78$%
Alternative Hypothesis, $\mu < 78$%
T-test, Level of Significance ($\alpha$) = 0.05, $\alpha = 61.33$ %,
Population Distribution (N) = 3
Standard Deviation ($s$) = 9.81 %,
$T = -2.9452$ is less than value $T = -2.9200$ so Null Hypothesis ($\mu_0 = 78$%) is rejected and alternative hypothesis $\mu < 78$ % has been accepted.

Case I,
Null Hypothesis, $\mu_1 = 77.80$%
Alternative Hypothesis, $\mu < 77.80$%
T-test, Level of Significance ($\alpha$) = 0.05, $\alpha = 61.33$ %,
Population Distribution (N) = 3
Standard Deviation ($s$) = 9.81 %,
$T = -2.9098$ is greater than value $T = -2.9200$ so Null Hypothesis ($\mu = 77.80$ %) is accepted and alternative hypothesis $\mu < 77.80$ % has been rejected.

Remanufacturing service is not only helpful for cost saving but also useful to save the lead-time to enhance the productivity. As shown in Table
5.5, lead-time save due to remanufacturing is around 50 to 70%; hence, companies are able to complete their production in scheduled time. Saving of lead-time is enhancing productivity and profitability of organization. Remanufacturing operations saves huge material and energy, which lead to reduce the lead-time. For getting the value of actual lead-time saving, T-test was applied on values shown in Table 5.5. Average Lead Time saving is around 61.33 % and maximum lead-time saving due to remanufacturing is considered as 78 %. Detailed test is explained in the Table 5.5.

Case I is rejected, so Case II has been conducted. Null hypothesis is accepted hence actual lead time saving due to remanufacturing is 77.80%.

5.16 Cost Saving Impact due to Remanufacturing

![Figure 5.8: Cost Saving Due to Remanufacturing for Ink Cartridges](Source: Ink Guide, 2009)

According to Ink Guides Company, many industries are making huge profit by selling remanufactured cartridges. Fig.5.8 & 5.10 shows ink and toner cartridge brands and cost saving due to remanufacturing over OEM. In ink cartridges, HP and EPSON are saving around 65 % manufacturing cost
due to remanufacturing. In toner cartridges, Lexmark, Canon brands save about 60% manufacturing cost due to remanufacturing. Due to huge cost saving, companies can offer a competitive price for remanufactured products. Here, company can earn more profit in remanufacturing the product as compared to new one.

Ink Guide indexes well over 10,000 ink and toner cartridges from 10 well known online ink stores. Fig. 5.9 & Fig. 5.11 show sale volume of remanufactured ink and toner cartridges as compared to new sale of cartridges by OEMs. Simply, the printer brands with the maximum volume of sold cartridges are listed in both figures.

![Figure 5.9: Sale Volume of Remanufacturing ink Cartridges (Source: Ink Guide, 2009)](image)

Customers are more attracted towards remanufactured cartridges due to good quality and low price. Quality of remanufactured cartridges and new cartridges are nearly the same, but price of remanufacturing cartridges are nearly 30 to 40% less than new cartridges in the Indian market. In ink cartridges Dell, HP, Epson and Lexmark make very good business as compared to other brands. From Fig.5.8 and Fig. 5.9, it can be seen that
there exists a strong relation indicating that the cost saving due to remanufacturing ink cartridges has shown huge impact on the sale.

Toner cartridges, Lexmark, Canon, Xerox and HP save huge amount of cost due to remanufacturing (See fig. 5.10). Canon and Xerox saved around 60% cost due to remanufacturing; hence company can sell the product at a
competitive price to grab major market share. Fig. 5.11 shows the sale volume of remanufactured toner cartridges.

5.17 Analysis of Impact of Cost Saving on Sale

Table 5.6 & 5.7; show the impact of cost saving due to remanufacturing on sale of remanufactured products. Lexmark and HP remanufactured ink cartridge have shown major impact due to cost reduction on sale but remanufactured Canon & Lexmark toner cartridges have not shown too much impact on sale due to cost reduction.

**Table 5.6: Correlation between Cost Saving and Sale Volume of Ink Cartridge**

<table>
<thead>
<tr>
<th>Ink Cartridges Printer Brand</th>
<th>Cost Saving Due to Remanufacturing for Ink Cartridges</th>
<th>Sale Volume of Remanufacturing Ink Cartridges</th>
<th>R</th>
<th>R²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canon</td>
<td>33%</td>
<td>11%</td>
<td>0.5771</td>
<td>0.3331</td>
</tr>
<tr>
<td>Brother</td>
<td>51%</td>
<td>03%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lexmark</td>
<td>55%</td>
<td>58%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HP</td>
<td>65%</td>
<td>48%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Epson</td>
<td>65%</td>
<td>30%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Table 5.7: Correlation between Cost Saving and Sale Volume of Toner Cartridge**

<table>
<thead>
<tr>
<th>Toner Cartridges Printer Brand</th>
<th>Cost Saving Due to Remanufacturing for Toner Cartridges</th>
<th>Sale Volume of Remanufacturing Toner Cartridges</th>
<th>R</th>
<th>R²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canon</td>
<td>60%</td>
<td>14%</td>
<td>0.16455</td>
<td>0.0270</td>
</tr>
<tr>
<td>Xerox</td>
<td>36%</td>
<td>22%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lexmark</td>
<td>60%</td>
<td>25%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HP</td>
<td>31%</td>
<td>36%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Konica Minolta</td>
<td>12%</td>
<td>12%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
From the analysis, it is very interesting to find the correlation between cost saving due to remanufactured cartridges and maximum sale volume of remanufactured cartridges (see Table 5.6 & 5.7). COC between cost saving by remanufactured ink cartridges and maximum sale volume of remanufactured cartridge is 0.5771 and the COC between toner cartridges remanufactured and maximum sale volume of remanufactured cartridges is 0.16455. Remanufactured ink cartridge value shows not so strong or too weak correlation i.e. $R=0.5771$ & $R^2=0.3331$ and remanufactured toner cartridge has shown a very weak correlation i.e. correlation does not exist. In remanufactured ink cartridge, COD shows the value of 0.3331 and hence dependency of cost saving due to remanufactured cartridges is 33.31% for maximum sale volume of remanufactured cartridge.

### 5.18 Cost Associated with Remanufacturing Operations

![Figure 5.12: Remanufacturing operations and Cost](image.png)

In remanufacturing operations, it is important to study the cost required to perform these operations. In remanufacturing operations,
mainly sorting, disassembly, finding part source, cleaning, refurbishing, part replacement, reassembly, inspection and packaging are the main operations. From fig. 5.12, it is clear that the cost required for part refurbishing and part replacement is more.

Near about 65% respondents, felt that the part-replacement is a costly operation in remanufacturing and 53 % felt that the part replacement is costly. Companies can reduce the cost of remanufactured products by concentrating on part refurbishing and part replacement operations. This cost reduction will be useful for gaining more profits in the market. From the case studies, it is proved that the cost saving due to remanufacturing is about 60 to 70 % of new product. Through the descriptive analysis using the questionnaire, it was found that the cost saving due to remanufacturing is in the range of 31% to 70%. This cost saving has motivated remanufacturers to grab the market share.

5.19 Cost saving Percentage due to remanufacturing

![Figure 5.13: Cost Saving due to Remanufacturing](image)
Cost saving percentage due to remanufacturing is explained in fig 5.13. Total 122 respondents from the industries have replied to this research question. 27.28 % of respondent said that the cost saving due to remanufacturing is around 51% to 60% of new counterpart product. 88.47 % respondents feel that cost saving due to remanufacturing is in between 31% to 70%. Based on the questionnaire and case studies, it can be concluded that the cost required for a remanufactured product is less compared to new products and cost saving is the predominant factor in business and hence the hypothesis $H_{03}$: Cost incurred for a remanufactured product is less than cost incurred for a new counterpart product has been accepted.

In short, the Original Equipment Manufacturers are always opposing the free globe trading of remanufacturing products in India due to fear of product cannibalization of new products. However, the Indian market has huge potential for remanufactured products and cartridge industries have shown remarkable impact of remanufacturing in the last decade. Remanufacturing industries are still in fancy stage in the Indian market and incoming years; it is expected to show a very positive impact in the market. Government of India should permit the free globe trading of remanufactured products for boosting the economy of the country. In this research, case study of an OEM has been conducted to understand the effect of remanufacturing services in the market. In this research work, case study of DMW has been studied and it is proved that the cost incurred in remanufacturing is less compared to that of the new product. Timken industry is seen providing the remanufacturing services to their clients Essar Steel Hot Mill, Lafarge Cement, Tinplate Company of India and Usha Martin for EOL bearings and mill chock. Remanufacturing of EOL bearings and mill
chock on an average resulted in 57% of cost saving as compared to new price. To calculate the nearby value of cost saving due to remanufacturing, a T-test was conducted on observed values were noted as shown in Table 5.4. Analysis shows that 74.88% of the cost is saved due to remanufactured products. Remanufacturing facility also reduces lead-time up to 77.80 % and this helps in improving productivity. Remanufacturing facility also reduces lead-time and this helps in improving productivity. It is seen that Timken has earned healthy profits through remanufacturing services. Remanufactured product didn’t cannibalize the sale of new products and instead it increased overall profit of OEMs. Many industries like Timken are also helping their customers through remanufacturing repair services. It is necessary for a company like Timken to introduce small to medium size remanufactured bearings and it should be brought into Indian automobile shops for sale. This will really help boost the awareness about the product to the customers. In cartridge industry, remanufactured version of cartridge cannibalizes the sale of existing cartridge but overall profit of companies is increasing well. In remanufactured ink cartridges, many brands are saving more than 50 % manufacturing cost as compared to new cartridges and price is also competitive and hence companies as well as consumers are enjoying the benefits.