Reverse Logistics in the Heavy Machinery Industry

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Abstract -- Due to recent changes in environmental regulations and the increasing cost of raw materials and commodities, managing product returns has received widespread attention from both practitioners and academicians. This document investigates the fundamental concepts behind the development of an integrated reverse logistics system. In order to develop a sustainable process into a competitive initiative, companies of several kinds of businesses have incorporated a reverse logistics process into their regular operation. For many companies, the reuse/recycle of materials and products can help earn money and at the same time build an image of being environmentally responsible. Finally, a case example is shown to highlight the procedure of reverse logistics in Caterpillar, a heavy machinery manufacturer. This example illustrates the remanufacturing process of components (e.g., high horsepower diesel engines) for mining equipment, which helps reduce cost for the customer and at the same time helps build Caterpillar’s environmental sustainability image.

Index Terms-- Caterpillar, heavy machinery, heavy duty engines, remanufacturing, reverse logistics, supply chain, sustainability.

I. INTRODUCTION

Reverse logistics is well-documented in research, but still has much room for implementation and improvement in practice. In today’s tough economic and competitive climate, companies need every competitive edge to be successful. Having an efficient process of moving goods and information from the point of consumption to the point of origin can help sustain and even expand the company. The aim of this paper is to explore reverse logistics and understand how reverse logistics applies in practice through a real-world example in the heavy machinery industry – Caterpillar (CAT).

II. BACKGROUND

As late as 1995 supply chain was defined as “a network of facilities that procure raw materials, transform them into intermediate goods and then final products, and deliver the products to customers through a distribution system”[1]. Reverse logistics is integral in defining supply chain for contemporary firms. To be a successful business in today’s world it’s important for a company to have a well-established supply chain which is able to move goods forward efficiently along with a sophisticated reverse logistics system. Rogers and Tibben-Lembke [2] have defined reverse logistics as the following:

“the process of planning, implementing, and controlling the efficient, cost effective flow of raw materials, in-process inventory, finished goods and related information from the point of consumption to the point of origin for the purpose of recapturing value or proper disposal” (p. 2).

Reverse logistics can also be used for remanufacturing or refurbishing purposes. The importance of reverse logistics is not limited to any particular business, industry, or company. Use of reverse logistics can be seen in cosmetic, food, software, automobile, heavy equipment, household goods, etc. It is believed by a few firms effective reverse management gives great opportunity to please customers [2]. Figure 1 shows the relation between forward supply chain and reverse logistics.

![Diagram showing the relation between Forward logistics and Reverse Logistics](image)

**Fig. 1: Relation between Forward logistics and Reverse Logistics (Own source)**

In 2002, logistics cost was estimated to be $921 billion (i.e. 9.9% of US economy and reverse logistics cost was estimated to be approximately $37 billion, causing management of reverse logistics to be strategic agenda on large number of industries [3]. Reverse logistics is also becoming an important component of retailer and manufacturer profitability and competitive position. Various governmental policies and other environmental legislation forces manufacturers to take-back used goods from customers to ensure proper disposal; recycle or remanufacturing [4]. With the growing popularity of customer awareness and different go green campaigns, one of the most effective way manufacturers can recruit new customers and retain existing ones by ensuring proper disposal of used goods.

Scarcity of resources leads to recapture of material and reuse of product or equipment. However, readily available cheap materials and advancement in technology, have led developed societies into mass consumption and routine throw away [5]. Method of routine throw away was practiced before the 1970s when sustainability and saving environment was not one of the major concerns [6]. Rather, all the concern was about growth and development and manufacturing more. The drawback with manufacturing more is generation of more by-
products which needs proper disposal or value addition to continue into the supply chain, resulting in more physical transportation of goods from end user to manufacturer.

To solve the problem of disposing used products and by-products, companies use a variety of disposal methods: landfill, incineration, recycling, remanufacturing, selling to outlets and donating to charities.

The most common methods are landfill and incineration. These are the options which should not be considered first because most of the industrial countries have saturated land space. Also, western countries have high tolls for this disposal method and there are a few products that can no longer be placed in landfills [7]. Recycling is sought highly for disposal as it generates revenue, produces a usable product, saves energy and resources, and saves landfill space and reduces landfill fees [7].

Remanufacturing or refurbishing is generally used for the automotive industry, spare parts, heavy machinery, domestic appliances, and the electronic industry. For remanufacturing, the manufacturer tries to receive the used product back, finds useful parts, and with the used parts they remanufacture a similar product. In the refurbishing method, the manufacturer tries to fix the product without losing the product’s identity [8]. Selling via outlet or discount refers to the method by which a manufacturer takes back the unsold item and sells it in factory outlet stores where the items have higher margin of profit than in general outlet. This method of disposal is prevalent among manufacturers of brand sensitive goods such as Nike shoes or apparel [2].

Secondary market in which vendor sells goods to established firms who expertisel’s in buying surplus, salvage goods for as low as 10% of the original price and sell it as a markdown item [2]. Donating it to charity helps firm receive tax reduction. Sometime goods can also be sold via auction; secondary store on internet. This cost of selling goods via internet is sometime still cheaper than sending it back to manufacturer or disposing it off [9]. In reverse logistics, product enters the reverse flow cycle from various reasons and channels.

Product is returned simply because it doesn’t work properly, its reached end of its life or it simply doesn’t do its job. Product can be returned using the following channels: manufacturer; distributor; retailer or consumers.

- Return from Manufacturer: The manufacturer returns the raw material to supplier if raw material is excess, it doesn’t passes the quality check or production leftover [5].
- Returns from Distributor/retailer: They returns the product for various reasons such as damaged in transit, expired, dysfunctional, tampered, packaging issue, product discontinuation, seasonal goods, excess inventory at retailer, retailer going out of business, recycle or simply for proper disposal[10]. It can also be returned due to recall from manufacturer, retailer was unable to sell the product, due to pre-existing contracts between manufacturer and distributor/retailer.
- Returns from Customer: They return the product if it doesn’t work, warranty returns, end-of-life; end-of-use return, service returns [5].

We can also see how the return percentage varies significantly in different industry. Table 1 lists the percentage of return of product for different industries.

<table>
<thead>
<tr>
<th>Industry</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electronic Distributors</td>
<td>10-12%</td>
</tr>
<tr>
<td>Computer Manufacturers</td>
<td>10-20%</td>
</tr>
<tr>
<td>Auto Industry</td>
<td>4-6%</td>
</tr>
<tr>
<td>Consumer Electronics</td>
<td>2-3%</td>
</tr>
</tbody>
</table>

Managing returns is one of the most challenging tasks. Effective return process can be achieved by managing efficient gatekeeping, compact disposition cycle-time, information system, customer service and technical support center, reverse transportation domestic and international, warehousing, return of material authorization (RMA) management, web-based returns.

In this paper, the industry example that is used to analyze reverse logistics in practice is CAT. CAT is a globally renowned manufacturer of heavy engines and construction equipment [11]. CAT’s remanufacturing (reman.) business started in 1972 as a result of a relationship with Ford Motor Company [12].

Ford had select Cummins over CAT Diesel Company to supply diesel engines for a new Ford delivery van. This decision came as a shock for many because Cummins at the time dominated the diesel engine business in part because Cummins kept costs down via remanufacturing of used engines. Seeing this, CAT realized that CAT too would have to keep costs down and boost CAT’s knowledge base to stay competitive and keep the contract with Ford. Thus, after thorough analysis, CAT decided to open a remanufacturing plant in Bettendorf, Iowa, close to the Peoria headquarters. For CAT, this new plant would serve as a test bed for reman.

Approximately 10 years later, CAT was convinced that CAT’s reman. efforts were growing in the right direction so CAT uprooted the reman. activities to an abandoned factory building in Corinth, Mississippi. The new Corinth location had its major advantages: the land was cheaper and there was a convenient abundance of road networks. Three years later, CAT opened a second reman. plant across town in Corinth. And not too long afterwards, CAT opened a third facility in Prentiss, Mississippi [13].

III. SUPPLY CHAIN MODELS

Reverse Logistics Processes

De Brito & Dekker [5] described the following process involved in reverse logistics and they can be aggregated in following five main processes:

a) Collection: Involve the transport of the product from the customer to a point of recovery.

b) Inspection, selection, sorting: In these processes, products are inspected and sorted according the quality state and planned recovery option.
c) Re-processing: Includes the following operations: repair, refurbishing, remanufacturing, retrieval, recycling and incineration.

d) Direct recovering. This process involves re-use, re-sale and re-distribution.

e) Re-distribution. This process involves the process of bringing the recovered products to the users. Issues and challenges.

IV. ISSUES AND CHALLENGES

The implementation of reverse logistic in a supply chain has some challenges that manufacturers and retailers have to face in order to get the mutual benefits for a reverse logistic scheme. Among these issues we can mention the following ones: conflicts between retailer and manufacturer, problems in the return process and poor information system.

Retailer–Manufacturer conflict: The retailer returns products as a method of reducing inventories near to the end of a period (i.e. a quarter). Retailers can return the products to the supplier suddenly. In order to avoid issues, retailers should communicate the supplier about the product return operation.

In the other hand, suppliers (manufacturers) can delay to recognize the return of one product because it impacts the sales of an accounting period.

According to Rogers and Tibben-Lembke [10], in an event of product or material return, the retailer and the supplier (or manufacturer) may disagree on any of the following:

- Condition of the item. Retailer and supplier can be disagreeing regarding the condition of an item being returned. One item can have defects from the manufacturer or can be damaged in transit to the retailer or a product can be damaged by the retailer.

- Value of the Item. The retailer may claim receive a full credit for an item, but the supplier may have some reasons to deny full credit.

- Timelines of response. The way and time the retailer receive the refund from the supplier can be an issue to discuss.

Finally the supplier and retailer needs to communicate about the product return operation in order to avoid issues, retailers should communicate the supplier about the product return operation. In the other hand, suppliers (manufacturers) can delay to recognize the return of one product because it impacts the sales of an accounting period.

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Problems in the return process: Some problems in the reverse logistic scheme come from the return process. According to Rogers and Tibben-Lembke [10], Dr. Richard Dave of the Fritz Institute of International Logistics identified six symptoms of these problems:

- Returns arrival faster than processing or disposal
- Large amount of returns inventory held in the warehouse
- Unidentified or unauthorized returns
- Lengthy processing cycle times
- Unknown total cost of the return process
- Customers have lost confidence in the repair activity.

The return process of products or materials requires the coordination in the supply chain (supplier-retailer-customer). Large amounts of return inventory in warehouses or large number of unidentified or unauthorized items show problems in the reverse logistics process. Delays in the process impact negatively the performance of the supply chain.

Poor information system: The effectiveness of the reverse logistics process depends on a reliable information system. Poor data collection doesn’t allow knowing the return causes. Improving the return process and efficiently handling the returned products decreases costs. The reverse logistic process needs to be monitored in order to be measured and managed properly.

V. INDUSTRY EXAMPLE: CATERPILLAR

Caterpillar Remanufacturing Operations: Caterpillar’s 797 hauling truck series is used for mining and construction and the current generation, 797F, is one of the world’s largest hauling trucks [11]. Please refer to Figure 2a, 2b for images of the CAT 797F and a picture of the CAT 797F engine, respectively.

Fig. 2a: CAT 797F (3rd Generation) Mining Truck, 2b: CAT

797F Mining Truck in Action [11] As found in CAT catalog provided below are some relevant specifications for this heavy-duty machine and the CAT 797F engine:

- Weight: approx. 623, 690 kg (1,375,000 lb)
- Top Speed (Loaded): 67.6 km/h (42 mph)
- Gross Power: 2983 kW (4,000 hp)
- Engine Model: CAT C175-20
  - 20-cylinder engine
  - Has 4 turbochargers
- Electronically-controlled common-rail fuel system
  - Deliver multiple injections in a single combustion
  - Accounts for low emissions
- Meets EPA Tier 2 emission standards

CAT’s Corinth reman. plant (a.k.a. Sawyer Road plant) serves as the central U.S. hub where all used engines and assemblies (such as that of the CAT 797F) from across country are sent from dealers. These dealers send around 160 tons of used equipment (~ 17 truckloads) to Caterpillar for reman. every day. Items such as engines, oil coolers, injectors, fuel pumps, and hydraulic assemblies are disassembled by hand. As an example, it takes two workers and half a day’s work to break down an engine into the individual parts. Caterpillar’s policy is that anything thrown in the trash is equivalent to money thrown away so
employees are taught to save every piece of equipment no matter how seemingly trivial (e.g. tiny screws) [13].

After complete disassembly, the next step in the remanufacturing process is to clean the components. The majority of the salvaged parts are coated with oil, paint, grease, carbon build-up, or rust from use so Caterpillar uses a mixture of baking soda and 10% alumina grit to remove the waste. Next, the cleaned parts are sent to inspection and sorting. The remaining waste from cleaning the parts is collected and used as a reagent to neutralize acidic liquid waste. This neutralization process makes both liquids non-hazardous and has helped Caterpillar reduce annual liquid waste from 9 million pounds to 4.5 million pounds [13].

Unsalvageable parts are passed to the company’s foundry in Mapleton, Illinois and melted down for recasting. This recycling process enabled Caterpillar to recycle 5,680,509 pounds of steel, 235,526 pounds of aluminum alloy, and 16,865,767 pounds of cast iron in 1999[13].

Caterpillar’s second plant in Corinth (a.k.a. Cardinal Drive plant) handles the remanufacturing of diesel engines, blocks, crankshafts, and other components. Eight engine models and the variations of the eight models are remanufactured here. The remanufactured engines are updated with current design standards and tested carefully before being transferred to shipment. These remanufactured engines also have the same warranty as new engines.

A majority of used engine components with worn surfaces undergo a strengthening process through thermal spraying, laser cladding, and welding. The components are then machined, grounded, and honed. Caterpillar also uses thermal spraying to eliminate chrome plating operations. In addition, Caterpillar has a proprietary process for repairing cast iron cylinder heads. The process enables CAT to repair small holes in engine blocks caused from the engine throwing a rod.

Finally, Caterpillar’s third plant in Prentiss, MS manages the returns of components to the original equipment manufacturers (OEMs) [14]. Please refer to Figure 3 below to see an overall flowchart of Caterpillar’s remanufacturing operations.

Caterpillar also aims to design and produce higher quality parts from the beginning since CAT has learned that 2-3 additional product lives are obtainable by following this design practice. For example, manufacturing an additional 1/16th inch layer of metal on a component may increase costs, but Caterpillar knows that this investment will yield eventual profits since the improved product can be remanufactured more times. Caterpillar estimates that a good engine can be remanufactured three times before the engine becomes totally unsalvageable. By following this design practice, Caterpillar’s Corinth operation was able to report more than $1 billion worth of sales in 2005 [13].

b) Caterpillar Remanufacturing Practices

Caterpillar acquires additional savings by recycling and reusing common work materials. For example, the wood pallets used for equipment transportation are routinely inspected, repaired, and reused. When the pallets become unfixable, the pallets are sold to a packaging company to be used as boiler fuel. Such remanufacturing systems are also in place at Caterpillar for aluminum cans, computer equipment, cardboard packaging, and office paper. Caterpillar’s Corinth plant reuses or recycles an extremely high percentage of CAT’s waste stream. In fact, the program is so successful that local schools, government offices, and 15 nearby industries have taken note and adopted similar programs [13].

c) Caterpillar Return Incentives

Maintaining a steady, incoming stream of used equipment is one of the main challenges in remanufacturing. A company can receive a large amount of used products one week and receive nothing in the following weeks afterwards. Caterpillar deals with this problem by offering incentives for customers to return used equipment. For example, when a customer needs a new equipment part, the customer is first requested to turn in the old one. When the old part is received, Caterpillar rewards the customer with a new part priced at half of the full price. However, if the customer refuses to return the old part, Caterpillar charges the new part at the full price.

Caterpillar also grants customers up to seven months to return engine cores. After the 7-month deadline expires, extensions are usually granted to allow the customer more time to return the engine core [13].

![Caterpillar Remanufacturing Supply Chain for Engine Cores](image)

Fig 3: Caterpillar Remanufacturing Supply Chain for Engine Cores (Own Source)
d) Caterpillar and Carbon Credits


Bauma is an exhibition for construction and mining machinery from all over the world [15]. Carbon offsets refer to the reduction of greenhouse gases in one location to offset emissions generated in another.

Caterpillar was able to offset 1,182 tons of carbon dioxide (CO2) emissions created from setting up the 9,500 m2 stand at Bauma [11]. CAT was able to calculate this emission total by partnering with Carbonfund.org, a leading nonprofit carbon reduction and climate solutions company. The emissions were offset via environmentally-conscious use of electricity and paper, lodging, transportation of staff and equipment, and meals. The offsets were used to support coal mine methane (CMM) capture project at a decommissioned coal mine in Luensen-Brambauer, Germany [11].

Methane is a byproduct of coal mining and is particularly harmful to the atmosphere (about 23 times more potent than CO2). Capturing this methane leaking from the coal mine is beneficial for both the environment and for use in power generation. Offsets such as this are consistent with Caterpillar’s internal eco-friendly practices and Caterpillar uses carbon credits in this way to reduce carbon footprint and reach sustainability goals [11].

However, Caterpillar has recently voiced negative opinion of cap-and-trade policy and has backed out of the U.S. Climate Action Partnership (CAP). One of the reasons may be that capping emissions may hurt industries CAT depends on for sales [16]. Instead of focusing on capping emissions, CAT is leaning support towards carbon tax [17] and carbon capture and storage projects [18].

e) Caterpillar Remanufacturing Issues

One of Caterpillar’s biggest challenges in remanufacturing is its centralized warehousing system. Currently, all engine cores and parts are shipped to Caterpillar’s Sawyer Road Corinth plant, even those from international locations. Only the core of the engine is shipped to Corinth for remanufacturing because that is the vital part of the engine that needs remanufacturing. Once there, the engine cores are broken down, cleaned, remanufactured, and generally sent back to the dealers where the cores originally came from. It is unlikely to sell the remanufactured cores in the U.S. because of stricter government regulations on manufacturing so the remanufactured cores tend to go back to the less strictly regulated international locations. Clearly, this system has a high transportation cost and lead time.

Consequently, CAT is talking about shifting a significant portion of their reman. process to China so that CAT can have footprints in China before the reman. market gets saturated. There are various benefits and risks associated with outsourcing CAT’s reman. activities. If Caterpillar were to set up a remanufacturing shop in China, CAT could not only lower transportation costs and lead time dramatically, but also could take advantage of the cheaper labor costs [14]. Furthermore, there would be increased flexibility in the ability to better respond to changes in customer demand [19]. However, the problem with China is piracy and copywriting and CAT will have to deal with those issues [14]. In addition, CAT wants to focus on its core competency and needs to carefully select what specific skills, talent, and knowledge sets to outsource. Outsourcing CAT’s reman. process to China may lead to loss of competitive knowledge and proprietary issues, especially in a country like China where copywriting laws and piracy regulations are quite lax in comparison to the U.S. [14].

VI. SUMMARY

Caterpillar is looking at several pathways to improve its remanufacturing business. Firstly, CAT is looking at how to improve its tracking systems on returns. Since engine cores come from all over the world, tracking equipment parts becomes a critical issue. Radio Frequency Identification (RFID) and two-dimensional bar coding are methods that can help CAT with this problem. In RFID, a tiny, low-powered radio transmitter is installed into each part to be tracked. This transmitter broadcasts a very faint signal that is just strong enough such that the signal can be detected by receivers in a warehouse. In two-dimensional bar coding, a number or code along with a description and other text must be translated by the computer and matched with the proper information. This lies in contrast to one-dimensional bar coding, where only a number or code needs to be translated and matched. Since reverse logistics processes are often filled with exceptions, using two-dimensional bar coding may be more efficient for tracking.

CAT is also looking at how to reduce the lead time on its returns. Currently, if a customer from China wishes to return an engine core to CAT, the core needs to be transferred to the CAT dealer in China, and then shipped all the way to the Corinth plant in the U.S. This takes a considerable amount of time so CAT has been discussing whether to expand its reman. business into China. Setting up a new reman. plant in China may save costs, but core competency and proprietary issues are a big concern.

While Caterpillar’s reman. business accounts for only approximately 4% of sales, CAT’s reman. business remains the most stable in times of economic crisis. CAT’s reman. business generates roughly 4% or more of CAT’s sales during tough economic times, which is still a sizable amount of revenue that should not be ignored. Thus, a significant amount of money can still be made or saved by implementing and improving reverse logistics processes. So while reverse logistics is unlikely to become the majority of companies’ primary source of revenue, reverse logistics can still serve as a crucial competitive advantage, especially in tough economic conditions such as today [14].

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