Initial Assessment on Feasibility of Remanufacturing Practice: Case of Air Conditioners

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***Abstract*- Due to the environmental regulations and economic viability, many industries show growing interest in the product recovery. Product recovery strategies (sometimes called end-of-life (EoL)) are recycling, remanufacturing, reuse, and refurbishment of components. Remanufacturing is a process that brings end-of-life product to its "like-new" conditions, the process recover product functions and quality, the remanufactured product is as its equivalent new with same warranty and less purchasing price. The price difference is associated with saving in energy, material and other resources recovered from the EoL product. The air-conditioning is the most energy consuming sector in Saudi Arabia (the geographical location of the study) where it consume 60-70% of the total residential energy. This study provide initial investigation and assessment of Business models for remanufacturing of window air-conditioner., a survey regarding the customer behavior has been conducted, it assesses how users deal with EoL Air-Conditioner, it also measures their perceptions about the remanufacturing process. Moreover, the paper describes the importance of remanufacturing in the context of reverse logistics. Results show that the cost structure is the driving force of conducting the remanufacturing of the air-conditioner.**

Keywords: **Remanufacturing; business model of remanufacturing; air conditioner.**

I. INTRODUCTION

Due to environmental regulation and economic viability, industries are showing the growing interest in the product recovery. Product recovery options some time called end-of-life strategies are recycling, remanufacturing, reuse, and refurbishment of components as can be seen in figure 1.

The process of disassembling the usable parts for the reuse in newly manufactured product is called reuse. While service cycle of these parts has to be defined clearly. Then the process where used products are restored to like new condition by a certain process of cleaning, disassembling, inspection and assembling is defined as remanufacturing. Sometimes products are modernized and upgraded to new specification.

Refurbishment part or components are cleaned and repaired for reuse or resell. Moreover the processed to basic form and used as new material for manufacturing new product is called material recycling.

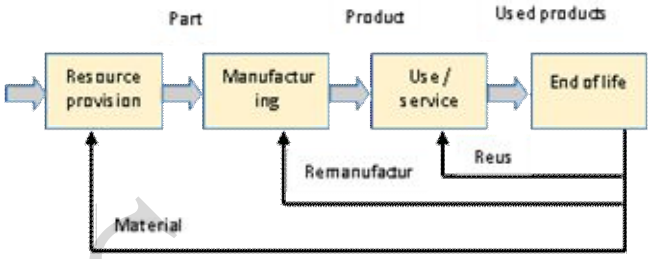


Fig. 1: End-of-life strategies.

Among all the end-of-life strategies remanufacturing is the profitable end-of-life strategy options, where the product recovered the quality level of a new product. The cost of remanufacturing is 40–60% of the cost of manufacturing a new product. Furthermore, a remanufactured product is sold at 30–40% discount with the same or better warranty as applicable for a new product [1]. Weather the product is suitable for the remanufacturing or not depends on the decisions taken in the early stage of the design process. Understanding the relationship and the dependency between the product design and development and the remanufacturing will be the effective approach.

Design for remanufacturing facilities the designer to take optimum decisions to improve the efficiency of remanufacturing considering the environmental and economical viability. The practice of remanufacturing is particularly applicable to complex electromechanical and mechanical products which can, when recovered, have value added to them which is high relative both to their market value and to their original cost. Studies indicate cost savings in the range of between 20 and 80%, when compared with the cost of new manufacture, while providing quality comparable with that of an equivalent, current, all-new product. Although remanufacturing has had a low profile, it has been a viable economic activity for many decades. [1]

It is commonly stated that 60% to 70% of the residential energy consumption in Saudi Arabia is consumed by air conditioning. Saudi Manufacturers estimate that the number of window air conditioners in the Kingdom is in excess of 10 million units with a replacement rate of over 1 million units a year. The market size is 2 million ACs per year. [2]

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In this study a survey has been conducted (figure2) which depicts the customer behaviour about the remanufacturing and how is the customer dealing with their air conditions after its end-of-life, the results were 8% of them will return it to the manufacturer, while 38% of will throw it away. moreover 34% of them will sell it in Al- Haraj (recycling yard), in addition 10% are going to do other things (Donation, storage, etc.) with their air-conditions.

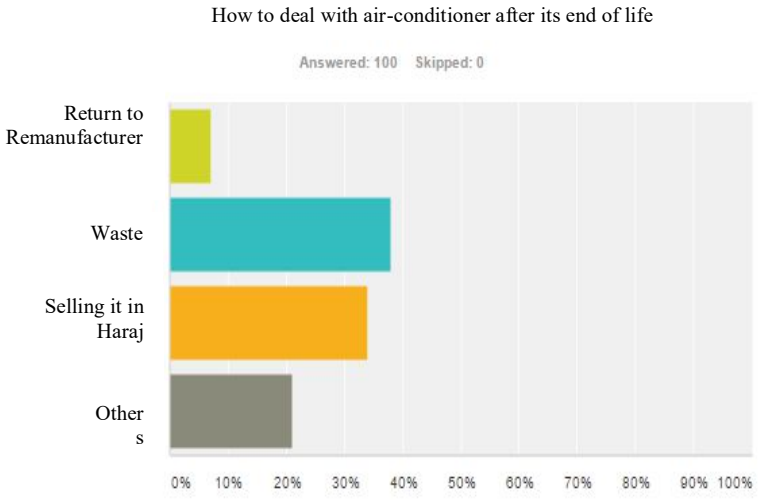


Fig. 2: Customer surveys

The survey found the air conditioner statistics shown in table1.

Table I. Unit Size, Type and Number per Household

Region	Central	Western	Eastern	South
Median number of ACs	4	4	5	3
% Window Units	61%	83%	71%	53%
% Split Units	39%	17%	29%	47%
Average Window Tonnage	1.6	1.3	1.6	1.4
Average Split Tonnage	1.9	1.6	2	1.6
Total Tonnage	6.87	5.40	8.58	4.48

These estimates correspond to a total of 13,315,000 residential window air conditioners in Saudi Arabia. These estimates provide one of the scenarios for the economic analysis in this study. [2]

II. AIR CONDITIONER LIFETIME

The survey conducted during this study found a customer replacement schedule produce 82.7% replacement by the end of year 10. This is considered unrealistic. The manufacturers estimate that the average replacement occurs after year 10. For this analysis we have estimated the average lifetime of a window air conditioner at 10 years and the average lifetime of a mini split at 15 years. [2]

The assumed survival rates of the window and split air conditioners are shown in figure (3).

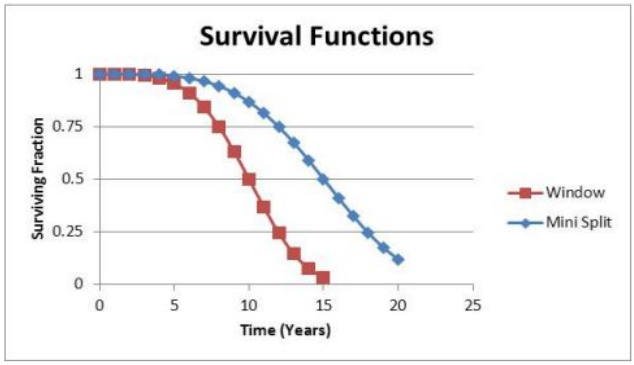


Fig. 3: Window and Mini Split Survival Functions [2]

III. COST

Retail AC Prices

The average price for the most common Window unit (18,000 BTU) is 1238 SR.

Total Cost at the Manufacturer

The total costs at the manufacturer for the most common units are:

18000 BTU Window Units 553 SR.

Component Costs percentages at the manufacture are shown in table 2 below

Table II. Estimated Component Costs [2]

	Window AC	
Component	US DOE	Replacement Parts Based Estimate
Compressor	28%	30%
Motor and Fans	10%	12%
Condenser Coil	7%	8%
Evaporator Coil	5%	8%
Controls	11%	
Other Materials	19%	
Labor	19%	

IV. REMANUFACTURING CLOSED LOOP SYSTEM

First of all the resource is taken as a raw material to be manufactured in the facility plant, and then it's sold to the retailers, the retailers sell it to the costumers as a new product, and then the customers use it till it reaches its end-of-life where the product becomes unusable. When the product becomes unusable, the customer returns it to the manufacturer where the remanufacturing takes place to remanufacture the product.

V. CRITERIA FOR SUCCESSFUL REMANUFACTURING

Some products are remanufactured able, such as machinery and engines. And the remanufacturing works best when some criteria are met. These are: the product has a high value, the technology in question does not change quickly, also fashion or trends in the product do not change quickly.

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However, the product is durable and is easy to disassemble, furthermore is leased or delivered as a service instead of hardware. Where this occurs there are shared motives for product durability, longevity and performance.

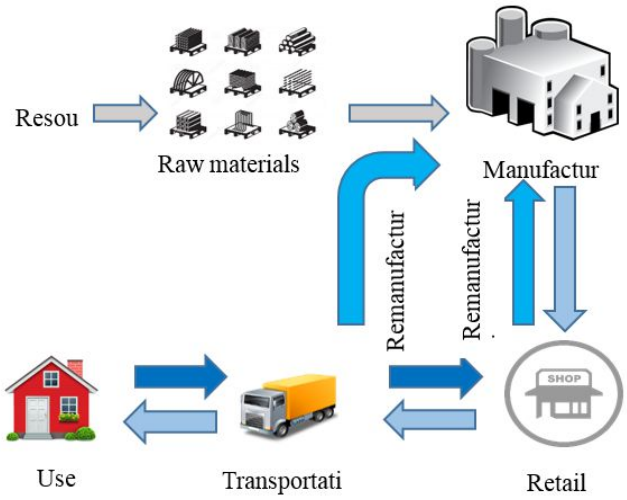


Fig. 4: Remanufacturing system

When the consumer returns a product to the remanufacturer, it enters the remanufacturing supply chain. There will also be other products at various stages in this supply chain at the same time, with some of these at the end stage of storage.

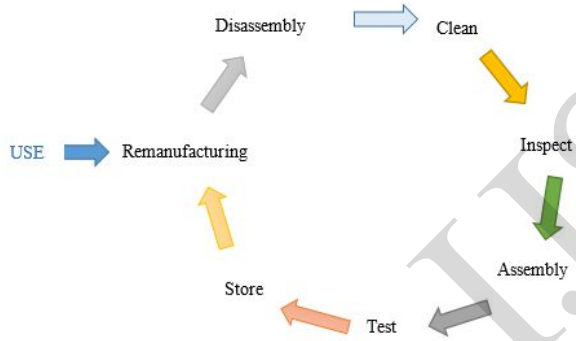


Fig. 5: Remanufacturing Process

VI. ACTIVITY AND RESOURCES FOR REMANFACTURING

Window Air conditioner used in most homes and apartments permanently, especially in Riyadh the weather always hot, according to that, the air-conditioner is working most of the day. So that the air-conditioner is very important thing in every place or rooms. In addition, difficult to live without it.

Our aim is to remanufacture air conditioners, when the customer has no further interest in the air conditioner; we take them and start the remanufacturing process according to the following steps. First, disassembly the air conditioner. Then, clean the air conditioner components. Next, Change some of the damaged components that are not be remanufacturing. After that, inspect all components of air conditioner before reassemble. Then assembly the air conditioner. Next testing the conditioner in air-conditioning test lab. Finally, Storage.

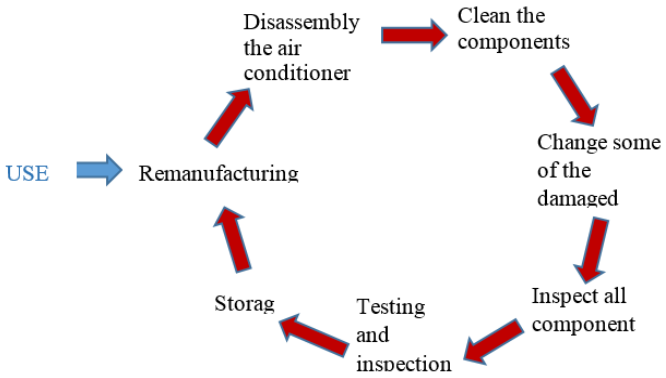


Fig. 6: Remanufacturing process

VII. MAXIMIZING THE PROFIT

After disassembling, the air-conditioner there will be many components as shown in Figure (7).

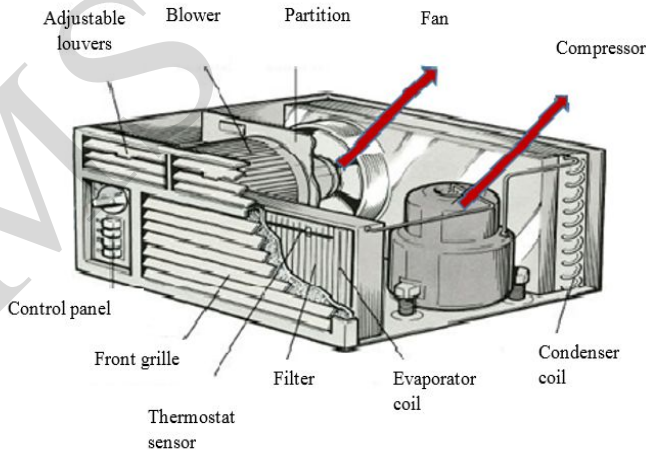


Fig. 7: Air conditioner components [4]

In addition, the most valuable and most expensive component is the compressor, since it is the heart of the air-conditioner and it is the most important thing. And when comparing repair, remanufacture or buy a new one, repairing as the main option for the management of end-of-life products can help reduce the use of natural resources and can also be economically and environmentally beneficial. Repairing Air condition parts can potentially reduce the greenhouse gas (GHG) emissions associated with a remanufactured or new compressor. [3]

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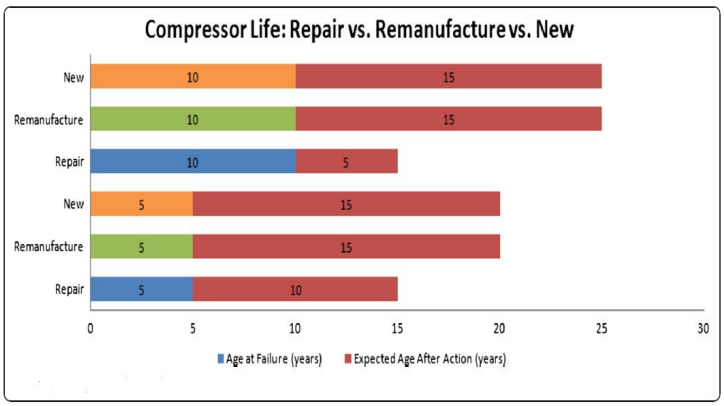


Fig. 8: Compressor life [3]

From a short-term perspective, repairing compressors can potentially reduce the GHG emissions associated with a remanufactured or new compressor. Biswas 2013 also found that lifetime durability matters more than the manufacturing processes. Remanufacturing can offer significant carbon-saving benefits rather than repairing from a long-term perspective. Finally, in the case of either repairing or remanufacturing, it is crucial that the replacement with energy- and carbon-intensive new parts be avoided to increase the carbon-saving benefits. [3]

VIII. CUSTOMERS BEHAVIOURS

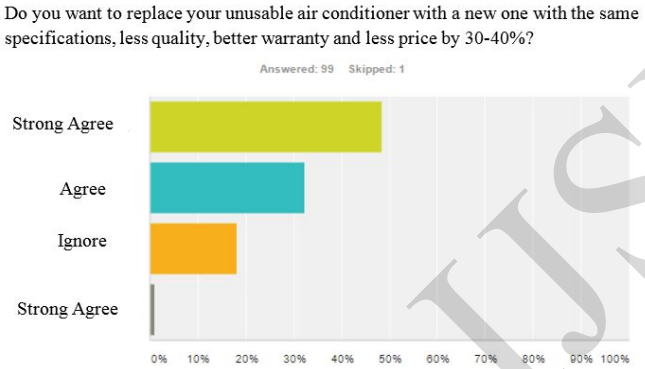


Fig. 9: Survey for customers

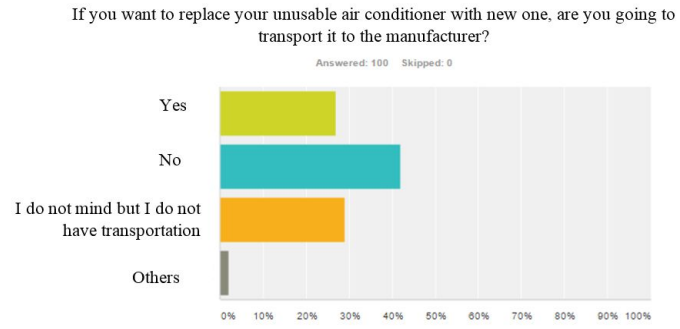


Fig. 10: Survey for customers

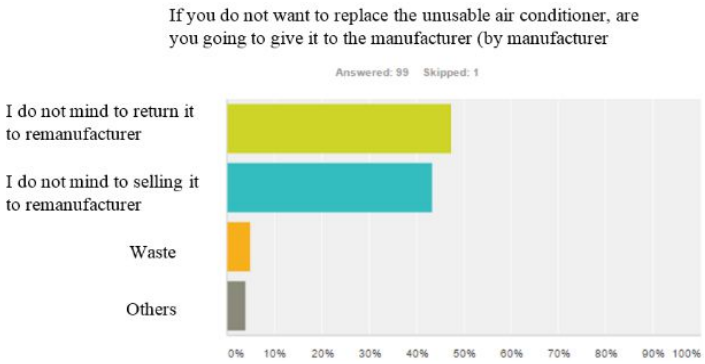


Fig. 11: Survey for customers

IX. CONCLUSION

Manufactures have options to improve their performance in conserving natural resources; adoption of more energy efficient technologies in their manufacturing processes is common trend in today's industries. Manufacturers are continuously improving their manufacturing processes to maximize the utilization of their input materials and reduce their environmental pollution. Product service system is relatively new business models that manufacturers are considering as an option to improve their sustainability. This model assign the ownership of the product throughout its life cycle to its manufacturer, customer pays for the functionality of the product than owning the product itself. This model gives the manufacture more control on the product design and its life cycle phase; this control enables them to provide more sustainable products

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