

# Remanufacturing as a Tool for Mechanical Waste Management in Developing Countries

Oluwafunbi. E. Simolowo, *Member, IAENG* and Ademola E. Owoo

**Abstract**—The rate at which mechanical equipment are being abandoned at the end of their useful lifetime is highly significant in the last couple of years, so much that it is becoming an endemic problem in the society, most especially in Nigeria(Africa). Generators are of particular concern because aside from automobiles, generators is the next in rank among all mechanical equipment due to its high production volume/importation rate as well as high market demand/usage as an alternative power supply in the developing countries. This work is aimed at assessing the potentiality of remanufacturing as tool for developing a waste management system for generators in a developing country like Nigeria; Results obtained from the analyses of data harnessed from the three companies investigated showed that there is 67% agreement that suggest the high prospect of remanufacturing generators thereby converting a lot of waste to wealth in a developing nation like Nigeria.

**Index Terms**—Developing countries, mechanical waste, management system, remanufacturing.

## I. INTRODUCTION AND RESEARCH BACKGROUND

The primary focus of this research work is to investigate the rate at which mechanical equipment like generators are being used and abandoned and to review the efforts being made by the importing /assembler companies of these products as a formal sector against the activities of private workshop owners (informal sector) in terms of level of remanufacturing of generators. It will also bring to the forefront the attendant environmental, economic and socio-political benefits of converting waste mechanical equipment to wealth. (M-waste to M-wealth). Remanufacturing Is a product recover measure that injects some economic value into the product as well as rid the environment of the escalating deterioration and degradation with a singular aim of minimizing the amount of waste materials sent to the landfills. When products are recovered, large amount of energy are being saved and virgin materials are better conversed for future and proper use while capital needed to produce new products are put into better use (profitable business opportunity). Environmental pollutions are also highly reduced. Developing nations like Nigeria have been at the receiving end vis-a-vis a dumping ground for numerous consumer products from the developed world.

Manuscript submitted July 10, 2015. Oluwafunbi. E. Simolowo is a Senior Lecturer in the Department of Mechanical Engineering, University of Ibadan Nigeria (phone: +2348059541882; e-mail:esimmar@yahoo.com). Ademola E. Owoo is a post-graduate student at the department of Mechanical Engineering University of Ibadan Nigeria

Therefore, large scale generation of mechanical waste is imminent within the country and the increasing trans-border movement of large quantity of end of life mechanical equipment into developing countries requires a viable strategic approach in recovering this product and the most prominent among the recovery option is remanufacturing. Gaudette and Giuntini [1] consider remanufacturing practice as the most evolved form of recycling: Remanufacturing conserves not only the raw material content but also much of the value added during the processes required manufacturing new products [1]. The energy used to remanufacture a product, is, on average approximately 20-25% of that required for an ex-novo manufacture (New remanufacturing), while the remanufacture cost is equal to about 60% of the original [2], [3]. The recovery options are used for several categories of products among which are: Aerospace and aeronautical, Automotive, Industrial machinery, gaming machines, data communication systems, robot, electrical and electronic equipment, ATMs, compressors, refrigeration appliances and others. Literature search reveals that about five million cars and mechanical equipment are discarded annually in Japan out of which 3.5 million are disposed of by domestic car dismantling companies and 1.5million are exported to developing countries [4]. Unlike in Europe where remanufacturing has been a common industrial practice for many decades, remanufacturing is a fairly new concept in China, with recent interest due to the dramatically rising number of vehicle on Chinese roads in the recent years [5].

Remanufacturing is an industry worth £5 billion per year in the UK and has been identified as a potential contributor to sustainable development [6]. Remanufacturing can offer a business model for sustainable prosperity, with reputed double profit margins alongside a significant reduction in carbon emissions [6] and 15% of the energy required in real manufacturing [7]. It can also be argued that most of the US remanufacturers operate in the automotive sector, about 70% of the total. No coincidence that the automotive industry has a long tradition in the recovery of engines but also of other vehicle parts, which can be used in several lifecycles before the final disposal. [8]. The United States is the world's largest producer, consumer, and exporter of remanufactured goods. Remanufacturing activities are not limited to only the countries mentioned above, it is also prominent in countries like Canada, Korea, Mexico , New Zealand, Russia, Singapore and others. Preliminary study reveals that none of the sectors in developing nations like Nigeria have any

physical work plan or road map required to prevent end of life products from being dumped in the landfills or rather bringing out the economic value from discarded product. Shown in Table 1 are selected that are remanufactured around the world.

TABLE 1:  
COMPANIES ENGAGED IN REMANUFACTURING AT  
INDUSTRIAL LEVEL

Industrial Sector	Products	Firms in Database	Estimated Firms not in Database	Total
Automotive	Alternators, Starter, Motors, Water pumps, Clutches and Engines	4536	46000	50536
Compression and Refrigeration	Air conditioner and Refrigerator Compressor	55	100	155
Electrical Apparatus	Transformers, Electrical Motors and Switch gear	2231	11000	13231
Machinery	Machinery and Equipment for various industries	90	30	120
Office Furniture	Desks, Files and Partitions	220	500	720
Tires, rethreaded	Truck, Auto and Off-road Tires	1210	180	1390
Toner Cartridges	Laser toner cartridges and jet cartridges	1401	5100	6501
Valves, Industrial	Control & Relief valves	110	300	410
Other	Divers	50	200	250
<b>Totals</b>		<b>9903</b>	<b>63410</b>	<b>73313</b>

The concept of primary and secondary markets is connected to the several possibilities of product recovery and to different prices of recovered products. [9]. Remanufacturing concentrates on activities higher in the value chain than reuse or recycling, considering cost-effective expenditure of materials, energy and time [10]. Other areas connected with remanufacturing include disassembly modeling process, demanufacturing, and automation of remanufacturing processes [11-21].

## II. RESEARCH METHODOLOGY

The aim of this study is to institute a practical recovery plan of remanufacturing processes for used machines in their large quantities, at their supposedly End of life period and probably channel a road map of operation. To achieve this research aim, three notable companies were investigated based on their activities on importation, assembly, sales and services of generators in Nigeria. They are; (i) Mikano Engineering Nig. Limited, Lagos. (Assembler of Perkins and Hyundai Engine) (ii) Mantrac Nig. Limited, Lagos. (Assembler of Caterpillar, CAT and Cummings Engine) (iii) Briscoe Motors Nig. Limited, Lagos (Assembler of Atlas Copco, FG Wilson and Lister Peter, LP Engine). The levels of remanufacturing activities in these companies were critically investigated. It was in the course of investigation that the activities of the informal sector (workshop owners) were brought into notice and taken into consideration. Shown in Figure 1 are some of the abandoned generators at one of the case study sites.

A research survey was designed to target three categories of audience. Category A comprises of senior managers, service managers and workshop supervisors and B comprises of workshop junior staff, assembly plant

workers and artisans all within the case study company while C comprises of owners of private workshops, generator mechanics and spare part dealers outside the case study. The Queries that were developed to capture the necessary data included: (i) determination of stage in the service life of a generator that it can be considered as end of life product (ii) availability of machine that can diagnose exactly when end of its service life is attained (iii) availability of options for customers to make do with their end of life product (iv) services/disposal procedure/regulation that are being scheduled by the company as available in other countries (v) availability of policies/legislations restricting disposal methods (vi) availability of tools/equipment that can facilitate remanufacturing process (vii) Company’s identification of the economic and the environmental benefits of remanufacturing (viii) availability of spare parts required for remanufacturing (ix) Consumer awareness and availability of markets for the remanufactured products. These among many were the series of queries directed to the numerous respondents in the three case study companies visited. The responses were analysed and the result were presented.



Fig. 1: Abandoned EOL generators in one of the sites of case study

## III. RESULT OF REMANUFACTURING SURVEY

The results of the research survey are presented in this section for the three categories of audience targeted as case studies. They are: category ‘A’ comprising of senior managers, service managers and workshop supervisors and ‘B’ are workshop junior staff, assembly plant workers and artisans while ‘C’ comprises owners of private workshops, generator mechanics and spare part dealers.

### A. Result Analyses for Category ‘A’

As shown in Figure 2, responses revealed a 100% agreement that the companies under consideration are among the leading assemblers of generators in Nigeria though the brands of engine they assemble are mostly invariant with each other. All the senior managers of the companies under investigation indicated that their companies render servicing and maintenance operations apart from assembly and sales of generators in Nigeria, this is called “after sales”. The companies under consideration also have a 100% response that they give warranties on all the products sold by them because warranty ensures customer’s confidence in product purchased. This is to establish the importance of warranty in purchasing and the awareness of an average customer on

warranty terms and conditions, all the companies under consideration stated they give warranties on all the products sold. More so, a 100% response from the companies also stated that the customers enthusiastically do claim their warranty if the need arises as far as the warranty period has not elapsed. From Figure 2, customers are expected to take full responsibilities of the expenses on the faults incurred on their generators when the warranty period has lapsed. The warranty period is given at 1000 hr/meter or at the end of one year. (Whichever comes first). In this case, all expenses including service charged by the companies are paid by the customers on any major break down or fault on the generator. A 100% response is recorded from the respondents that the customers take full responsibility

Figure 3 shows that remanufactured generators can perform as good as new ones. Figure 3 shows the level of agreement on whether diagnostic machines can be used to detect faults in discarded generators, just to facilitate remanufacturing process (but for selected brands only).

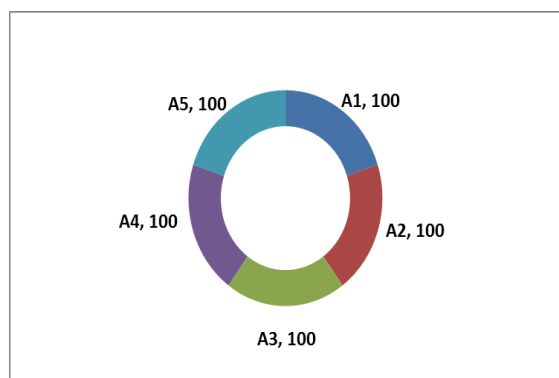


Fig. 2: Percentage Assessment of Company Status and Services

- A1 Company among leading assemblers of generators?
- A2 Ability to render sales after service?
- A3 Provision of warranty for all products sold?
- A4 Claiming of warranty if need arises?
- A5 Costumers accept responsibility after warranty period?

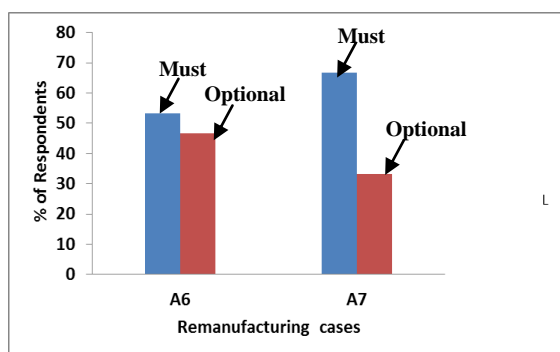


Fig. 3: Analyses of Product Performance

- A6 Necessity of partial and full overhauling?
- A7 Remanufactured products perform as new products?

From the Figure 4, 20% and 53.3% of the respondents strongly agreed and agreed respectively that the diagnostic machine can detect faults of generators and therefore facilitate remanufacturing process. 26.7% of the respondents were undecided i.e. they are not sure if it can be used at all or for all brands of generators. Invariably, a 73.3% of the respondents agreed that the diagnostic machine is efficient in

remanufacturing process by pin pointing the exact component of the generator that is bad. It was later discovered that not all brands of generators complied with the diagnostic machine. From Figure 3, 33.3% and 26.7% of the respondents strongly agreed and agreed that remanufacturing/refurbishing must commence after a generator has reached its end of life period. It also shows that remanufactured products can perform exactly like new product. Conversely, 20% and 13.3% of the respondents disagreed and strongly disagreed respectively with the assertion. 6.7% of the respondents were undecided. From the foregoing thus, 60% of the respondents agreed with the assertion.

Figure 4 also shows agreements of the respondents that some components are supposed to be reconditioned or replaced with new parts in remanufacturing and these parts are readily available in the local markets. One-fifth of the respondents agreed with this assertion while 66.7% of them disagreed. However, 13.3% of the respondents were undecided. This shows that parts are available in the local markets; however, the availability may be rare. This is one of the greatest challenges of remanufacturing in Nigeria because the OEM are not resident in the country. More so, The Figure 4 shows a 67% agreement (27% strongly agreed and 40% agreed) that remanufacturing process can create skilled employment and human capital development if properly harnessed. One-third of the respondents with 33.3% were undecided with this assertion. However, remanufacturing process being able to create opportunities can be piloted by government programs/policies and by public-private partnership or synergies among related companies.

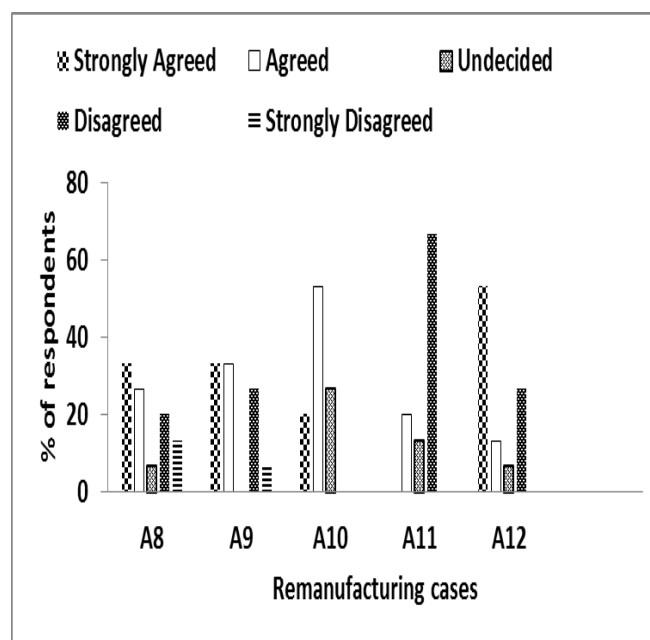


Fig. 4: Analyses of Remanufacturing Survey for Category 'A'

- A8 Possession of economic value by EOL generators
- A9 Diagnostic machines is useful in remanufacturing
- A10 Components for replacement of are available
- A11 There are ready markets for remanufactured goods
- A12 Remanufacturing can create skilled employment

### B. Result Analyses for Category 'B'

As shown in Figure 5, the analyses for audience 'B' showed that all (1000%) the targeted staffs of each company have the required skills and experience to carry out servicing, repair and maintenance on the ranges of generator that their company assembles. From Figure 5, ability to put a warranty on all refurbished generators had 46.7% of the respondents. This shows that they may not be able to consider venturing into remanufacturing activity for one reason or the other

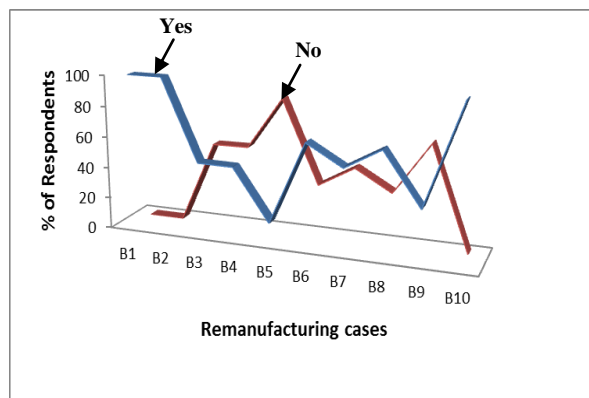


Fig. 5:Analyses of Remanufacturing Survey for Category 'B'

- B1 Possession of the required skill?
- B2 Availability of required tools?
- B3 Ability to completely remanufacture?
- B4 Ability to put warranty on all refurbished generators?
- B5 Readymade market for remanufacturing replacements?
- B6 Upgrade by new components in remanufacturing?
- B7 Remanufacturing includes: inspection, disassembly, etc.?
- B8 Payment of 60% of the total cost by the customer?
- B9 Availability of required experience?
- B10 Required tools to repair a particular brand of generator?

This is also an indicator to show that remanufacturing is yet to be seen as an economic viable enterprise by those company studied. The availability of a readymade market where all types of replacement parts (new) can be sourced in the case of refurbishing/remanufacturing is stated to be non-existent by 86.7% of the respondents while 13.3% of the respondents stated they are readily available. Majority of the replacement parts or remanufactured parts are sourced directly from the Original Engine Manufacturer (OEM) which are not resident in Nigeria. Remanufacturing will get its right footing by the time Nigeria starts producing these machines but in the meantime, a step towards remanufacturing now is a step towards industrialization.

The ability to upgrade by incorporating new/latest components parts into old machines so as to reflect the improvement that have occurred since the equipment was originally made was attested to be possible by 66.7% of the respondents while 33.3% stated that it is not possible.

The respondents were asked to state if the processes of remanufacturing are inspection, disassembly, part replacement/refurbishment, cleaning, reassembly and testing. From the Figure 5, 53.3% stated yes while 46.7% stated that they may not follow the procedure in sequence i.e. one may come before another like cleaning before disassembly or even testing before part replacement. The respondents also affirmed that products verified to be suitable for remanufacturing are sent to the Original

Equipment Manufacturer (OEM) with payment of 60% of the total cost by the customer accounted for 66.7% while those that stated no, only because their company do not remanufacture at all accounted for 33.3%. The parts of the old products are normally exported abroad to the OEM for reconditioning.

### C. Result Analyses for Category 'C'

From Figure 6, 33.3% of the respondents possess required skill and experience to carry out servicing, repair and maintenance on all the ranges of generator available in the market while 66.7% of the respondents stated their skill and expertise depends on some particular brands and not all. Therefore, most of the owners of private workshops deal in a particular brand of generator rather than the overall generator type. In fact most workshops are situated around/very close to the companies under consideration which shows that they only specialized in company related problem. In addition, Nigeria markets are over flooded with different brand of generators which is a disadvantage to remanufacturing. All the respondents with a 100% account stated they possess the required equipment/machines and tools to carry out servicing, repairing and maintenance on a particular brand they deal in. More so, the respondents that stated they possess the required equipment/machines and tools to carry out servicing, repairing and maintenance on all types of brand accounted for 33.3% while the respondents that stated they do not have the required equipment/machines and tools accounted for the majority with 66.7%. Therefore, most of the private workshop owners specialize in some brands of generators. Majority of the private workshop owners (93.3%) stated they have the ability to carry out a complete refurbishing/remanufacturing operation on generators while 6.7% stated they could not. This is in contrast with what we had from audience B and this is an indication that not all the case study companies actually engage in remanufacturing. Even those that do it only do it at skeletal level.

In furtherance with most of the respondents stating they have the ability to refurbished generators (Figure 6), 60% stated they could also provide warranty on the refurbished/remanufactured generators while 40% stated they could not. Customers are more comfortable with an impression that the risk they are taking can be shared in case there is a break down. Most of the respondents with 60% stated that replacement parts (new) in case of refurbishing/remanufacturing are available in the market while 40% stated they are not. This was in contrary to what the case study provided because audience 'C' does not have to depend majorly on OEM, rather there are spare part dealers all around. Exactly 100% of the respondents stated that there is a possibility of upgrade by incorporating new/latest components parts into old machines so as to reflect the improvement that have occurred since the equipment was originally made. Also, 100% of the respondents (46.7% strongly agreed and 53.3% agreed) agreed that there is availability of customers willing to purchase a remanufactured machine with or without warranty. The target has always been a secondary market where customer who cannot afford new generator set go for old remanufactured [OR]. The remanufacturing

procedures/steps are: inspection, disassembly, part replacement/refurbishment, cleaning, reassembly and testing. Exactly 66.7% of the respondents added to this while 33.3% of the respondents stated they do not follow the procedures, on the same reason as audience 'B.'

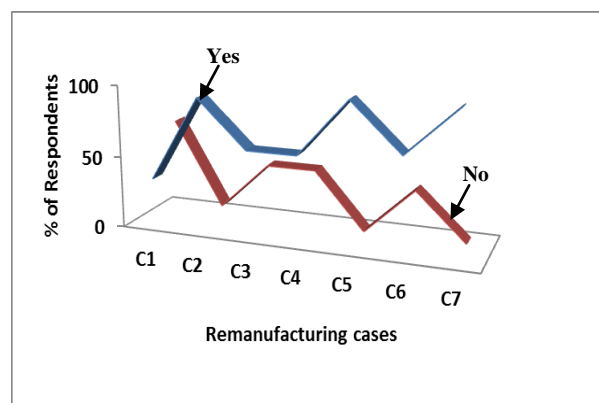


Fig. 6: Analyses of Remanufacturing Survey for Category 'C'

- C1 Possession of the required skill?
- C2 Ability to completely remanufacture?
- C3 Ability to completely remanufacture with warranty?
- C4 Readymade market for remanufacturing replacements?
- C5 Upgrade by new components in remanufacturing?
- C6 Following of remanufacturing procedure?
- C7 Advising customers for remanufactured

All the respondents stated from Figure 4 posit that they would not advise a customer to go for a new machine when the old ones can be successfully refurbished and even upgraded for better performance. This is also in contrary to audience A and B who majorly specializes in sales of new product, audience C trade only in old refurbished/remanufactured products.

#### IV. REMANUFACTURING AS A TOOL FOR MANAGEMENT OF MECHANICAL WASTE

In this section the prospect of remanufacturing as a tool for mechanical (generators) waste management based on the results of survey is analysed. In theory, any product that can be manufactured can be remanufactured but the design of some products' business model and detailed product design means that some products can be remanufactured more profitably than others. The criteria required for a product to be successfully remanufactured and sold based on 25 years of research into the remanufacturing industry are [11]: (i) Technology exist to restore product. Technology must be able to extract a component without damage. (ii) Product is made up of standard interchangeable parts. (iii) Cost of core is low relative to savings in product cost achieved through core reuse. (iv) Product technology is stable over more than one life cycle. (v) Sufficient market demand to sustain enterprise. (vi) An evaluation of disposal options and environmental impact of legislation is also necessary to determine a product's suitability for remanufacture [11].

The survey analyses done in this work have shown that some of these criteria for successful remanufacturing have

been met. The private informal enterprises have indicated availability of ready market (C4) in Figure 6, possession of required skill (C1) and ability to completely remanufacture with warranty (C3). The survey also shows that the staffs of the bigger companies have all the required skill as well as the necessary tools for remanufacturing (B1 and B2) in Figure 5. Upgrade is also made possible in remanufacturing while customers are ready to pay up to 60% of total cost (B6 and B8). Shown in Figure 7 are steps need to be considered before embarking on remanufacturing production system. Some of these facts have also been considered in this work thereby making remanufacturing a feasible venture in combatting mechanical waste such EOL generators.

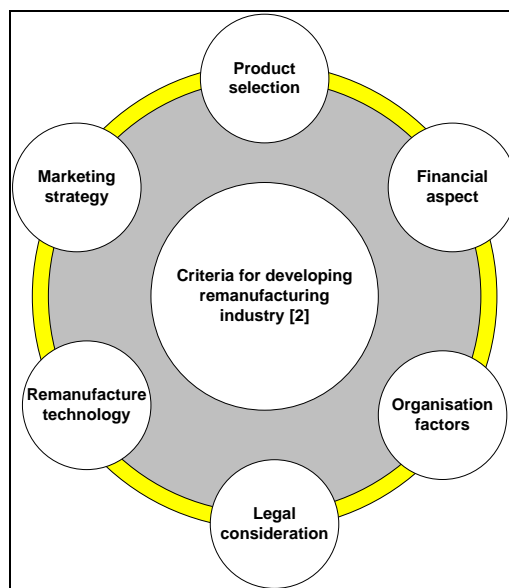


Fig. 7: Steps for developing remanufacturing industry

#### V. CONCLUSION

It can be concluded that, while the more organized companies see remanufacturing as secondary and give it a low priority due to the huge profit acquired from new sales, the private informal sector give remanufacturing a top priority in their little capacity. This brings about sizeable amount of old mechanical equipment being taken out of the junk yards, get remanufactured and sold to secondary market. Effort made towards remanufacturing will encourage the influx/importation of parts rather than new machines while the major assembler need to be more regulated so as take care of their end of life product. Also there must be a more proactive legislation that regulate the rate of dumping of all end of life product, by studying what is obtainable in other countries of the world most especially China. Remanufacturing if properly harnessed, can be used as a pointer on the road map of how to revitalize our moribund industrial sector, reduce the huge investment and capital flight on purchase of new generators. It will also help developing nations like Nigeria to develop skilled labor, contribute to a higher efficient energy savings which is the number one challenge in the whole world.

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