RECYCLE MATERIALS POTENTIAL OF IMPORTED USED VEHICLES IN NIGERIA

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Abstract

In the recent years, most developing countries have resorted to importing of used vehicles as a means of solving acute/shortage of transportation facilities. Some of these vehicles are so dilapidated that they never serve any purpose before finding their way to the junkyards and refuse dumps. This paper seeks to quantify the available salvage value/service materials potential from these imported used vehicles in Nigeria. Most of the streets in the urban areas and construction sites are littered with junk vehicles which were abandoned by their owners. These vehicles, many of which have actually reached their end-of-life are potential secondary materials as they can be recycled into the same product or something less, thereby creating economic, social and environmental benefits.

Keywords: end-of-life vehicles, recycling, imported used vehicles, secondary materials

1. Introduction

One of the effects of globalization is that goods and services can easily be moved from places of surplus to places of scarcity, from places of less demand to places of high demand and from places of rejection to places of acceptance, within a short period of time. According to Federal Road Safety Commission, Nigeria currently has not less than 7 million registered vehicles operating on its roads, whereby the road transport system accounts for over 75% of the mobility needs [1].Though this might be doubtful as a whopping number of these vehicles gets deregistered or gets scrapped on daily basis without official documentation. However, more than 60,000 vehicles are being imported into the country on yearly basis which translate to both metal and non-metal scraps at the end of their useful service lives [2]. Nigeria is therefore a major consumer of vehicles, but produces little.

But, in a nation where per capita income is about $2,700 a year, most Nigerians still opt for used cars, making the same sort of transition from subsistence earning to consumer spending that plays out across Africa's developing economies. About 50,000 vehicles valued above $2,000 each were exported to Nigeria from the U.S. in 2008, based on various official sources compiled by Export Trader. "Nigerians mainly import low-end, eight- to 10-year-old vehicles valued below $5,000; flooded, damaged and stolen cars often are imported" says VadymKozub, director of development for Export Trader [3]. All sorts of abandoned, discarded, wrecked, ruined, or worn out vehicles that cannot be repaired and put back into service otherwise called "end-of-life vehicles" (ELV) are found in Nigeria. They have value as a source of used parts, scrap material and other material for recycling and repair work. Nevertheless motor vehicles are the number one recycled consumer product in the United States [4].

According to the theory of circular economy, wastes are nothing more than resources in wrong place or not properly used, or the loss of specific value or function at certain stage, while they are still usable and can gain new using value through proper configuration [5]. In the course of creating immense wealth, manufacturing industry has exclusively consumed the resources and energy in the earth, and seriously polluted the environment. To take progress as the sustainable development way, save resource and improve environment, our nation has been advocating to construct the economy and saving- oriented society. Recycling reduces pollution and impacts global warming. When energy demand decreases, fewer fossil fuels are burned and less carbon dioxide is emitted into the atmosphere. Recycling creates jobs – according to U.S. Recycling Economic Information study, more than 56,000 recycling and reuse establishments in the United States employ approximately 1.1 million people, generate an annual payroll of $37 billion, and gross $236 billion in annual revenues [6]. Alongside efforts to prevent global warming by reducing CO2 emissions, waste treatment has become widely recognized as an important issue for building a recycling-oriented society [7].

Recycling has been labeled the most successful environmental initiative in human history. By changing the way resources flow through our society and communities, we can reap substantial environmental, economic, and social benefits. We save energy, water, resources, and landfill space. We reduce pollution of air, land, and water by using recycled materials. Reducing, redesigning, reusing, refilling, regenerating, recycling, repairing, reclaiming, refurbishing, restoring, recharging, remanufacturing, reselling, deconstruction, and composting are the constituents of zero waste and all provide productive employment and economic development opportunities. Designing for environment sustainability ensures that all costs including the environment are internalized at the design stage. On the environmental side, studies performed at the Fraunhofer Institute in Stuttgart, Germany found energy savings by remanufacturing worldwide in a year equals the electricity generated by five nuclear power plants or 10,744,000 barrels of crude oil [8]. Through remanufacturing, we can reduce resource extraction and energy consumption, two of the main contributors to greenhouse gas emissions. Zero waste will invariably put human society in harmony with nature.

1.1. Research objective and methodology

The main objective is to quantify the available raw materials potential of imported used vehicles. The paper also advocates for the extraction of recycle value from these nuisance ELVs. Due to lack of awareness and because a functioning infrastructure does not exist, littering and diffused losses of secondary resources are the non-sustainable reality in many developing countries. As the demand for environmentally friendly products continue to grow, the technology for converting post consumer waste into new products improves; and more recycling programs put in place, then the avalanche of used and dilapidated vehicles and parts being transferred to the weaker economies can there and then be reprocessed into new of the same or different products. Nigeria, therefore, can no longer continue to wait for the development of the ore mining industry or the iron and steel industry before ferrous and non-ferrous components can be manufactured. Her predicaments can therefore be turned into glory as waste scrap vehicles can be recycled into valuable resources.

The methodology of this research work is based on available statistics, secondary literature, interviews with identified stakeholders in the automotive business and the informal sectors including scrap scavengers.

2. The Concept of Recycling

Scarcity of raw materials, huge energy requirements for the industries and environmental concerns forms the bane of the innovations in recycling technology today. The driving force , criteria and concept for ELV recycling result from different factors that have changed with time, for example development of the electric arc furnace in the 1960s -1970s; production of high quality steel required the use of vehicle scrap free of nonferrous metals, prompting the magnetic separation of ferrous from non-ferrous metals. Further, the separation and recovery of aluminium from ELV was more energy efficient than production of aluminium from its ores. Other driving forces are social and environmental concerns towards sustainable waste management. Nearly 90% of automotive aluminium is recovered and recycled. Although this aluminium represents less than 10% of the average motor vehicle by weight it accounts for roughly half of the vehicles value as scrap. Auto recyclers supply more than one-third of all ferrous scrap (iron and steel) to the U. S. scrap processing industry [9]. When manufacturers use scrap iron and steel instead of virgin ore, they reduce air and water pollution by more than half during the manufacturing process. Cars are recycled in four steps: dismantling, crushing, shredding, and resource recovery (separation) from automobile shredder residue (ASR) which goes to land fill. It is worthy to mention that used vehicles have higher specific fuel consumption due to system deterioration and this can lead to high fuel use intensity in the transport sector due to unnecessary higher demands for the commodity.

The demand for recycled material and availability, and variety of products with recycled content continues to increase even though the profitability of the recycling programs themselves run by various state environmental agencies may be marginal or negative. However, companies that convert the recycled material into products benefit economically because their manufacturing costs tend to be lower than if they used virgin materials. Key factors affecting the use of recycled materials is the availability of post consumer waste; the cost to convert them to new products is often less than the conversion cost using virgin materials. Because much of the negative environmental consequences of aluminium, steel, paper, and glass production stem from the initial processing of the virgin materials, environmental regulations and their associated costs are very high. However it has been observed that recycled materials do not last as long as virgin materials [10]. This is only partly true as experience showed that "Awawa" – an unbreakable plastic bowl, has been acclaimed to outlive its virgin materials produced counterpart.

The number of ELVs per year recycled in the European Union (EU) could be less than the official figures 8 9 million as higher profits accrue selling these used cars intact rather than as spare parts and materials in the European Union. The high cost of disposal to landfill was one of the driving forces in the diversion of automobile shredder residue from waste disposal toward more eco-efficient treatments. The ultimate goal of the directive of European Parliament and of the council of 18 September 2000 organized former national policies and voluntary agreements, is to put only 5% of ELV residues (ASR) into landfills [11].

3. Trend of used Vehicles importation

The most important countries concerning the export of used vehicles in Europe are the neighbouring countries of Nigeria, Niger, Benin, Togo and Ghana. While Niger and Benin are final destinations of minor importance, Nigeria on the other hand is a very important destination for used vehicles due to the large population and importance of its economy for West Africa [12]. Table 1 shows the vehicle import statistics in Nigeria.

In Europe and the West the life span of a car in use is between 12 and 15 years. With an average life span of 13.5 years, in the year 2000 over 2 million cars and vans reached the end of their useful lives in UK, either because of old age or due to accident [13]. Most of the vehicles imported into Nigeria are between 5 and 15 years old officially, with some having actually passed their service lives.

According to overseas marketing information, India (OMI), more than 60% out of about 80,000 vehicles per year imported into Benin republic is re-imported to Nigeria [2]. This portends that Nigeria has become a healthy ground for the dumping and disposal of end-of-life automobiles as legislation bites harder in most of the industrialized nations of the world.

Transporters on their part would rather buy six used vehicles for say 30 million naira instead of buying one new vehicle for the same amount. This has the attendant consequences of higher environmental pollution, unreliable transportation, journey time and safety cannot be guaranteed, puts more stress on the commuters, and proves to be unreliable and uninsurable business venture.

4. Estimate of the Potential secondary materials

Typically an automobile would be composed of about 75% iron and steel, 2% of non-ferrous metals, 15% of rubber and plastics and 3% glass as structural materials. Indeed aggregate estimates of inputs for a viable local automobile industry indicate steel sheet and alloy requirements of 3,000,000 tons, plastics 30,000 tons and rubber 40,000 tons annually [14].

For an average saloon car production, it is estimated that the following figures should be budgeted for as follows in Table 2 below.

The composition of a typical car has changed substantially in recent years. For example, ferrous metal content has decreased significantly as lighter; more fuel-efficient materials such as plastics are incorporated into vehicle design. It is believed that a 100 kg weight reduction of a vehicle results in a fuel savings of about 0.7l/km [11]. A typical car weighs 1.3 tons some 20 years ago and now 1.1 tons with the incorporation of plastics and growth in aluminium content.

5. Harnessing and Harvesting the Secondary Materials

The actual choice of different materials for specific applications or products is determined by technical factors which include density, strength, modulus of elasticity, conductivity and thermal expansion, and economic factors which include purchasing price, cost of transformation, cost of maintenance, scrapping or disposal cost and scrap value which summed up gives the life-cycle costs of a material or product. Other factors like legal, trade restrictions or aesthetically preferences may affect material selection, but are usually neglected because they can hardly be quantified [16].

Product structures, materials, location of recycling facilities, applicable regulations, geography, and cultural context have a major impact on the economics and environmental benefits of material recovery [17]. Even in good faith situations the ELV directive has arguably incentivized the export of automotive waste from wealthier European countries to poorer ones by way of increased export of intact ELVs. Many less developed countries lack organized systems of waste management, and dangerous waste stream often flow undetected. Indeed, "closed loop" recycling offers potential cost savings to the producer, as all components in a new vehicle may be made from the same materials as a particular ELV [18]. Between 5,000-6,000 trucks each filled with second hand goods, often electrical and electronics plus 1,000 containers filled with second hand goods are shipped to Nigeria every year from Hamburg port in Germany [19]. Article 5 of Act on Recycling , etc, of end-of-life vehicles (Act No. 87 of July 12, 2002, Japan) on obligations of vehicle owners de-

Table 1: Vehicles Import Statistics in Nigeria.

		1993	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2005**	**2006**
Cars	New	5877	3908	2425	3067	3811	8479	5687	6292	10073	7369	12695	22527
	Used	110563	55405	27804	4596	2677	3886	20800	47856	98747	56593		
Buses	New	3906	1087	942	885	1048	1957	1512	2164	4657	4139	1408	3807
	Used	24794	19994	11745	2364	1128	1427	6825	14877	17146	13861		
Trucks	New	1135	1001	1864	2840	3705	1990	1803	1812	330	402	4288	4676
	Used	8279	8161	3632	1454	4030	2851	4892	9732	15901	13724		
Total New		10918	5996	5213	6792	8564	12426	9002	10268	15060	11910	18391	31010
Total Used		143636	83560	43199	8414	7835	8164	32517	72465	131794	84178	33134	43606
TOTAL		154554	89556	48412	15206	16399	20590	41519	82733	146854	96088	51525	71616

* Data source: Manufacturers, OMI India.

mands that owners shall endeavour so as to prevent vehicles from becoming end-of-life vehicles by using the vehicle for as long a period as possible, and endeavour to promote recycling, etc of end-of-life vehicle by purchasing recyclable vehicles and using goods obtained from recycling of end-of-life vehicles or goods using them [20].

One approach developed in industrialized countries over the last few years, is to reduce cost; nevertheless in developing countries where labour is cheap, lifetime extension and recycling work very well, the average life time of a car can be as high as 35 years compared to 12 years in Europe. Automobile take-back, dismantling, and recycling can have large associated costs: buy back of car (cost/car), this is dependent on condition and value of car type. In some cases, there may not be a buy-back cost. Transportation costs (cost/km) depend on weight and amount of damage tolerated. Trip and storage fees (cost/car), the property on which cars are stored also cost money. Labour cost (cost/hour), depend on the level of skill required. Equipment investment cost (cost) and operating cost (cost/car, cost/hr), influenced by the need for special and expensive equipment and the depreciation rate of the equipment. Time necessary to recover parts and materials (hr/car), is strongly influenced by the design of the vehicle. In order to obtain a profit, these costs have to be offset by revenues. Revenues in automobile recycling can be obtained from high value (high demand), undamaged recovered reusable components. Energy can be recovered and sold from incineration. On the demand side, the competitiveness of recycling is limited by a lack of preference for recyclable and secondary materials on behalf of processing industries, due to their technical properties limited applicability and/or negative image. Furthermore, recycling is likely to be hampered by the lack of pertinent industrial standards or even by the tendency for some standards or specifications to ignore or discriminate against recycled materials or products. The factors that determine the recyclability of single materials include the purity of the recovered products, the market for the recovered products, the monetary value of the material, the cost of collection and transport, the cost of sorting, the cost of transformation into reusable material and the cost of disposing of any residue material. The car as a central part of modern society is a product that differs from others, for example, in its documentation, potential scrap value, and physical size, it affords possibilities for a controlled end-of-life management [21].

The average value of the exported used vehicles to West Africa is quite low (below 2000 Euro per unit) with an average vehicle age of 12-16 years. About 20% of the exported used vehicles have got a malfunctioning engine. On the average, more than 3 million cars are deregistered in Germany every year of which approximately 540,000 are recycled in Germany itself and about 580,000 are exported according to German statistics. This leaves a gap of approximately 2 million vehicles per year. The export of about 2.5 million units of used vehicles represents a secondary material potential of about 1.3 million tons steel, about 180,000 tons aluminium, about 110,000 tons other nonferrous metals and finally about 6.25 tons platinum group metals [12,19]. The benefit statistics of remanufacturing 10,000 Styr engines were analyzed and the results show that remanufacturing engineering could use the maximal additional values of obsolete engines, and make contributions to materials conservation, capital saving, energy conservation and environment protection [22].Prior to creating a piece of equipment from recycled materials, several variables should be considered. First, can enough of the needed materials be obtained? Equipment made of recycled materials may have better quality, more versatility, or be more appropriate to a particular group's needs because the maker knew exactly how and by whom the equipment would be used. Individuals must weigh the cost/time factors as they pertain to their own situations [23].

The manual disassembly of parts and materials for recycling has however never been practiced by the majority of end-of-life operators. Even parts that have been designed for disassembly are not removed because of the high labour cost and low value of the removed materials. Although many separation methods are well established within the recovery industry, such as magnetic separation, eddy current separation and dense media separation; these methods are primarily for separating metallic substances. The value of many post-shredder material streams is dependent on material purity. The removal of negative value materials such as copper from steel and PVC from incinerator charge, manually could increase the value of many of the post shredder material streams [24].

Decisions in recycling involve the quantity of the common waste product to be recycled and the quantity and the selling price of each new product to be reproduced. Firms can form coalitions to make pricing and recycling decisions together, and thus the profitability of the firms can be boosted [25].With the rapid economic development of Taiwan and the resultant demand for improved quality of life, the number of motor vehicles has exploded in the past 30 years. A reward system has been established to reward people who voluntarily turn in their ELVs. Deserted ELVs on road sides are also identified and removed by the environmental police authority in accordance with the law. If nobody comes forward to claim the vehicle, it is disposed off as waste and auctioned off by the environmental police unit. However, some developing countries, such as Malaysia and Mexico, who are in the early stages of starting their ELV recycling system, lack ELV recycling regulations. The main objective of recycling ELVs in these countries is to recycle usable secondhand parts, which is driven by market conditions [26].

Table 2: Material Composition of an average saloon car.

Materials	**Wt/unit** (kg)
Sheet metal (body pressed parts)	337.5
Sheet metal (mechanical components)	37.5
Sheet (forged and machined components)	400.0
Cast iron	150.0
Aluminium and alloys	50.0
Copper	25.0
Lead	12.5
Paint/primer/sealant/ anti-rust	18.8
Glass	43.8
Rubber	75.0
Plastic	50.0
Textile and composite materials	50.0
TOTAL	1,250.0

* 1,250 kg per unit represents the average weight of a saloon car [15].

6. Recycling End-of-life Vehicles

To return the resources used in automobiles to the stock of resources available to use in automobiles, Toyota took up the challenge of developing recycling technologies for end-of-life vehicles (ELV). In 1998, Toyota, together with Toyota Metal Co., Ltd, developed technology for recycling/recovery of automobile shredder residue (ASR) from ELVs thereby constructing the world's first mass-production recycling plant, with a capacity of recycling about 15,000 ELVs per month. The sorted resin materials (solid and fuel additives) were utilized as fuel for electric furnaces [27]. Mazda Motor Corporation developed the world's first recycling technology in which used bumpers from vehicles, whose useful life has ended into raw plastic resin for use in new vehicle bumpers. Used bumpers vary considerably in terms of the composition of polypropylene plastic and the paints adhesive properties [28]. Plastic materials recovered from ELV bumpers still show a high level of mechanical strength and a good thermal stability. Recovered polypropylene can, therefore, be used in that state, without modification, for the fabrication of many parts for industrial and domestic goods [29].The level of sophistication required in technical products makes them complex in order to fulfill the functional and other requirements imposed on them. The steps in remanufacturing are: disassembly, cleaning, sorting, checking, reconditioning, and reassembly. At present many products are designed not to be disassembled in order to save on initial cost and discourage user ingress due to liability problems while others are produced as modular units or inserts meant to be replaced and not to repair.

One key materials selection decision with wide economic and environmental implications is the use of recycled or secondary material in production. The long-term sustainable usage of materials will require a robust secondary recovery industry. Secondary recovery forestalls depletion of non-renewable resources and avoids the deleterious effects of extraction and winning. One of the primary challenges for increased secondary raw material usage is due in part to the presence of high levels of unwanted or "tramp" elements, for example iron and silicon in the case of aluminium, particularly in post-consumer scraps. Dismantling of end of life products, spectrographic or magnetic sorting of shredded scrap, and "filtration" technologies such as fractional crystallization and vacuum distillation are some of the methods that remove tramp elements in the melt during casting operation. Other raw materials used in the iron and steel industry include scraps, especially in the production of low carbon flat products. There is a problem with this because of the presence of tramp elements and impurities in the scrap which might require extra refinement to remove before usage [30], see Table 3.There is however, a relatively new process of producing the steel components such as crankshafts, con-rods, gears, flywheel etc, which were traditionally forged in heavy forging machines, in heat treated cast iron called austempered ductile iron (ADI) which can be produced from scrap iron for which there is abundant supply in the country. The equipment required furnace and heat treatment plant is lower in cost and is economical for producing relatively low volumes. The components produced by this process, ADI, are as strong as the steel they replace and are cheaper to produce. Ford Motors, Chrysler, GM and more are reported as now producing automobile components by this method [31].

Non-ferrous metals like aluminium have also continued to gain an advantage in cast applications such as engine blocks and cylinder heads. In Japanese cars aluminium accounts for about 35% of the engine block. The process of aluminium recycling involves simply re-melting the metal, which is far less expensive and energy intensive than creating new aluminium through the electrolysis of aluminium oxide (Al2O3) which must first be mined from bauxite ore and then refined using the Bayer process. Recycling scrap aluminum requires only 5% of the energy used to make new aluminium. For this reason, approximately 31% of all aluminium produced in the United States comes from recycled scrap. As recycling does not damage the metals structure, aluminium can be recycled indefinitely and still be used to produce any product for which new aluminium could have been used. Brazil accounts for 89% world recycling rate

Table 3: Possible tramp elements that increase with recycling.

Material	Tramp elements
Steel	Ni, Cr, Sn, Cu, Zn
Plastics	Cd
Aluminium	Mg, Ni, Zn, Pb, Cr, Fe, Cu, V, Mn, Si, Te,
Brass	Pb
Copper	Fe, Pb, Ni, Cr, Sb, Bi, Se, Te
Glass	Al, SiC, C, Chromites, Carborundum
Cast iron	Mn, Ni, Mo, Zn, Co

in 2001, reaching 10.5 billion cans in number. Brazil attaches great importance to recycling aluminium beverage cans, 15 million people engaged in recycling aluminium beverage cans in 2001, a return rate of 85%, ranking first in the world, more than Japans 82% recovery rate [32]. Pistons have been produced using scraps and adding alloying materials that would make the pistons different from those in existence, to avoid infringing on patent rights [33].

To determine the gross limits on recycling rates, it will be necessary to forecast this demand growth, evaluate scrap recovery rates, and determine product lifetimes and compositional deterioration. Dilution and downcycling are current practices to mitigate the effect of high levels of unwanted, or tramp elements that prevent their increased utilization. Dilution is when secondary materials must be mixed with primary material in order to ensure the finished products meet compositional and performance specifications. While dilution is common; it has a negative impact on recycling as the required dilution results in a compositionally determined cap to recycling rates. Down- cycling is where materials are recycled into lower value products; it is another common method of dealing with highly contaminated secondary materials; this enables higher usage but negatively effects recycling economics [34]. Currently about 98% of the metals in a car are recycled. The most common automotive plastic types are polypropylene (PP), polyethylene (PE), polyurethane (PU) and polyvinylchloride (PVC). PP accounts for approximately 41% of all car plastics (common bumpers, wheel arch liners and dashboards), and like PE and PU (most common in seat foam) it is easily recycled. Viable markets for PP, PE and PU from non-automotive sources already exist. Treating vulcanized rubber with heat or chemical can produce devulcanized rubber. However, the variety of uses for this rubber has been limited due to its unreactive nature leading to poor bonding/strength. Tires have a high calorific value, about 20% greater than that of coal, which on burning can be harnessed to produce energy [13].

6.1. Existing Recycling Initiatives

Currently, there are some uncoordinated recycling of iron and steel, aluminum, and plastic components of ELVs in Nigeria. The iron and steels are being used to produce concrete reinforcement rods and flat steel sheets for the building and construction industry. The aluminium are smelted for the production of cooking utensils. Old vehicle batteries are used both internally and some are exported to countries like China where they are remanufactured, recycled and at times the cell components reused. The scrap scavengers go to different mechanic workshops collecting and buying disassembled and removed scrap components. Typical cost implications and uses are as shown in Table 4. The scavengers in turn supply these scraps to the smelting companies.

A 12m (40ft) length by 12 mm (1/2 inch) diameter rod produced from the Iron and steel scrap sold at N1330. This gives a material weight of 10.60kg with a calculated material content cost of N270. The materials were in most cases downcycled. The rods and sheets produced from these scraps could not be properly categorized and coded as they did not fall into any existing standard specifications. They show poor quality and incoherent behavior and there use in design is highly unreliable. These are caused mainly by the poor

Table 4: Cost of Disassembled Vehicle Scrap Materials.

S/N	Material	Cost (N)	Recycle Uses
1	Iron and steel	25 per kg	Rods, sheets, pan
2	Aluminium	150 per kg	Pots, spoons
3	Battery	1000 per 12V 100AH, 600 per 12V 60AH	Battery, jewelry, fish trap
4	Kick starter	200 per unit	Copper extraction, jewelries
5	Sparkplug	10 per unit	Plug remanufacture

* The exchange rate was N152 to $1 and N220 to 1Euro.

sorting of the scraps before charging them into the furnace. The other materials in the table also suffer the same fate. However, where properly sorted, the recycling takes advantage of the original virgin materials composition which is at times hoarded by the original equipment manufacturer to produce the same quality product.

7. Analysis and Results

Based on the average numbers of different categories of vehicles imported into Nigeria every year with their materials compositions see Table 5, this translates to more than 196,000 tons of scrap materials at the end of their service lives. The estimated annual vehicles requirements for the country are 20,000 cars, 15,000 buses, 40,000 trucks and tractors, and 30,000 tankers and trailers [15]. The materials requirements based on the vehicles need is presented in Table 6. The available material resources through the importation of used vehicles are also contained therein. From Table 6 it is observed that more than 36% of the materials requirements can be generated through recycling.

Table 5: Imported Vehicles Materials Content

Table 6: Material Requirements for the Auto Industry

8. Limitations

Many used vehicles find their way into the country through unauthorized routes. Importation of cannibalized engines and other aggregate parts are also substantial and which could not be monitored effectively. The vehicles come in different sizes and makes and although the normal weight distribution of raw materials input in a typical saloon car is about 62% steel, 12% cast iron, 7% non-ferrous alloy, 4% plastics, 6% rubber and others 9% there is no hard and fast rule on this distribution, since the advancement in engineering materials selection grossly and gradually upset this distribution. These, however, do not in a major way compromise the integrity of this work.

9. Conclusion

As ELV parts, which include metallic and non- metallic substances, are increasingly gaining recycling value due to the recent global shortage of raw materials, the establishment of proper recycling system for ELVs will not only reduce the impact on the environment during the recycling process, but will also facilitate the effective reuse of recycled resources. The environmental cost of entities that aggressively adopt and maintain a high level of recycling should be low relative to those entities that do not maintain an equally high level of recycling activity [35]. Recycling post-consumer aluminium to build new vehicles will further reduce manufacturing life-cycle energy consumption and emission leading to significantly lower production costs [36].

Shifting from the 3R concept (reduce, reuse, recycle) to the 6R concept (reduce, remanufacture, reuse, recover, recycle, redesign) may result in savings or gains for both manufacturers and consumers. It is essential to integrate the 6R criteria into all phases of the

Table 5: Cost of Disassembled Vehicle Scrap Materials.

Materials	Car matl/ unit (kg)	car matls %	car matl wt. (tons/yr)	Trk/Bus matl/unit (kg)	Trk/Bus matl %	Trk/Bus matl wt./yr (tons)	Total veh. matl import (tons)
Sheet metal (body pressed parts	337.5	27.0	16,399.6	2,100.0	30.0	47,459.2	63,858.8
Sheet metal (mechanical components)	37.5	3.0	1,822.2	140.0	2.0	3,163.9	4,986.1
Sheet (forged and machined components)	400.0	32.0	19,436.6	1,750.0	25.0	39,549.3	58,985.9
Cast iron	150.0	12.0	7,288.7	2,450.0	35.0	55,369.0	62,657.7
Aluminium and alloys	50.0	4.0	2,429.6	70.0	1.0	1,582.0	4,011.5
Copper	25.0	2.0	1,214.8	7.0	0.1	158.2	1,373.0
Lead	12.5	1.0	607.4	7.0	0.1	158.2	765.6
Paint/primer/ sealant/anti-rust	18.8	1.5	911.1	21.0	0.3	474.6	1,385.7
Glass	43.8	3.5	2,125.9	105.0	1.5	2,373.0	4,498.8
Rubber	75.0	6.0	3,644.4	140.0	2.0	3,163.9	6,808.3
Plastic	50.0	4.0	2,429.6	140.0	2.0	3,163.9	5,593.5
Textile and composite materials	50.0	4.0	2,429.6	70.0	1.0	1,582.0	4,011.5
TOTAL	1,250.0	100	60,739.4	6,000.0	100.0	135,597.6	196,337.0

Table 6: Cost of Disassembled Vehicle Scrap Materials.

Materials	**Yearly car requirement** (tons)	**Yearly Trk/Bus requirement** (tons)	**Total requirement** (tons)	**Import veh. matl percentage of total matl requirement**
Sheet metal (body pressed parts)	6,750.0	178,500.0	185,250.0	34.5
Sheet metal (mechanical components)	750.0	11,900.0	12,650.0	39.4
Sheet (forged and machined components)	8,000.0	148,750.0	156,750.0	37.6
Cast iron	3,000.0	208,250.0	211,250.0	29.7
Aluminium and alloys	1,000.0	5,950.0	6,950.0	57.7
Copper	500.0	595.0	1,095.0	125.4
Lead	250.0	595.0	845.0	90.6
Paint/primer/sealant/anti-rust	375.0	1,785.0	2,160.0	64.2
Glass	875.0	8,925.0	9,800.0	45.9
Rubber	1,500.0	11,900.0	13,400.0	50.8
Plastic	1,000.0	11,900.0	12,900.0	43.4
Textile and composite materials	1,000.0	5,950.0	6,950.0	57.7
TOTAL	25,000.0	510,000.0	535,000.0	36.7

vehicle development process to make it pay-off [38].There is need to intensify local sourcing of aluminium and stop exportation of scraps [38]. Cooperation between members in the ELV recycling system, including the government, manufacturers, importers, and sellers, dismantling/recycling operators, shredding plant operators, and the public, will increase the recycling efficiency, recovery, and reuse of resources which will eventually lead to a well established ELV recycling industry.

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