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REVIEW

Framework for sustainable management of end-of-life vehicles management in India

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Abstract

Automobile manufacturing requires different metals-steel, aluminium, copper, lead, chromium, nickel and zinc, as well as significant amounts of plastic, glass, rubber and fabric. Analyzing the direct and indirect raw material requirements in the Indian automotive sector during the period 1997–2007, it was found that the material requirement of the sector doubled in a period of 10 years [1]. End of Life Vehicles (ELVs) can also be an important source of secondary raw materials, such as metal and other materials, which if salvaged and/or reused/recycled, can be again fed into the economy thereby helping to close the loop of sustainable resource circulation and reducing the demand for virgin raw materials. Estimates suggest that steel scrap worth INR 115 billion can be generated in India from retired vehicles (that include two wheelers, three wheelers, private cars, commercial passenger and commercial goods vehicles) [2]. In this paper, the authors attempt to use the shared responsibility based framework to explore and develop a business model with a structure of stakeholder engagement for improving sustainability of ELV management in India. The management of end of life vehicles in the country has significant scope for improvements in material recovery and the proposed shared responsibility based framework can help in this context.

Keywords End of life vehicles (ELVs) · Shared responsibility · Business model · Recycling

Introduction

The increased consciousness of our surrounding environment and concerns linked to degradation of the same has led to many regulations around manufacturing and disposal of products of various kinds. Vehicles are one of the critical products that characterize consumer lifestyles, particularly that of the middle class segment of population in developing countries such as India. Estimates suggest that over the last decade, India has been experiencing one of the highest motorization growth rates in the world and had over 200 million motorized vehicles registered by 2015 [3]. With a vehicle's average life generally around 10 to 15 years, after which it is expected to enter the retired/end-of-life (ELV) phase, there is expected to be more than 8.7 million vehicles having reached the end-of-life phase by 2015, and this number is expected to rise to 21 million in 2025 [4]. Here, we would like to inform that the term ELVs covers all those motorized vehicles that are no longer in use—because they are no longer fit to operate or because they have become too expensive to operate. CPCB guidelines 2016 has given a break-up of the ELVs in India across various categories including two wheelers, three wheelers, private cars, commercial passenger and commercial goods vehicles. We use this categorization of ELVs for this paper.

ELVs can be an important source of secondary raw materials, such as metal and other materials, which if salvaged and/or reused/recycled, can be again fed into the economy thereby helping to close the loop of sustainable resource circulation and reducing the demand for virgin raw materials. For example, estimates suggest that steel scrap worth INR 115 billion can be generated in India from retired vehicles [2]. Further, by remanufacturing components and parts using those from ELVs, subject to it not being detrimental to their function, safety and reliability, can also promote circular economy in the sector.

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Currently ELVs in India usually end-up in the informal sector, such as the scrap yards at Mayapuri, New Delhi, or Pudhupet, Chennai. In these scrap yards, there is dismantling that happens using crude ways, after which the recovered auto components are either refurbished and sold in the second-hand market (directly to end use consumers or traders of second-hand parts) or the material resource is recovered from these components and sent for recycling (in many cases for down cycling). Although certain regulations have been introduced for better ELV management, yet lack of standard operating procedures, ambiguity in deregistration of vehicles, poorly informed consumer practices, prevent effective and sustainable management of ELVs. This calls for revisiting and understanding existing practices and the policies, and exploring opportunities that not only makes economic sense, but can create social values and prevent environmental degradation.

The European Union (EU), Japan, Korea and Taiwan present examples of countries having a product-oriented legislation that has been initiated to control the recovery of ELVs. These countries have recognized that a distinct ELV law is necessary within the framework of the extended producer responsibility (EPR) framework and have reported success in controlling the number of ELV off the road. Also the evolving global environmental awareness, shrinkage in availability of landfill area, and depletion of natural resources are among the factors which have driven a number of developing countries in adapting strategies towards management of ELVs.

In this paper, the authors recognize that environment being everyone's responsibility and not just that of recyclers or car manufacturers, but everyone who benefits from the automobiles. So they use the shared responsibility based framework that engages all stakeholders including auto owners and auto dealers and attempt to explore and develop a business model for improving sustainability of ELV management in India. The sustainability will not only focus on preventing environmental harm linked to ELVs, encourage proper recycling (by promoting recovery of materials and their reuse, reducing down-cycling), but will also help improve the quality of life of workers operating in crude ways and facing occupational safety and health hazards in the informal sector. To do this, first a SWOT (Strengths, Weaknesses, Opportunities and Threat) analysis is done for current ELV management in India. Learning from across the world is also drawn. A structure of stakeholder engagement required for generating economic profitability and social benefits in addition to the preservation of the environment, is also suggested in this paper. For the Indian scenario, it will be extremely important to also integrate the informal sector (where much of the end of life management of products happen) into the formal set up being proposed in the framework and not force them out of the system of ELV management. Integration into the formal set up will lead to scientific and environmentally safe management of ELVs by the informal sector, internalizing the social and environmental cost of ELV management.

Need for end of life management of vehicles-resource angle

One of the major issues that the world is currently grappling with is the unprecedented growth in demand for various resources and the associated challenge in meeting this demand. The outcome has largely been driven by the highly material intensive growth rates being experienced by the developing countries, as well as the continued high levels of material consumption in developed countries; although some evidence of absolute decoupling in certain developed regions of the world have been observed in recent times, led by the European Union (EU). Never in the past has the conflict between economic growth and resource consumption found such high attention by different stakeholders as has been observed in the recent times.

Developing countries' pressure on demand for resources is only likely to increase in the future due to many factors including growing population, rising aspirations of the vast middle class, demand for improved lifestyles and increased urbanization. According to UNEP-Data, India consumed about five billion tons of materials in 2010, out of which about 42% were renewable biomass and 38% non-metal minerals, fossil fuels and metals. Projections indicate that by 2050, the total consumption of biotic and abiotic materials will be nearly fivefold compared to 2010 and the share of abiotic materials will be four times that of biotic materials [5].

The current linear economy approach does not allow us to close the loop from production to consumption to secondary resource management and channeling of these resources back into the economy. The massive waste generation at all stages of a product life cycle right from resource extraction, processing, value addition, consumption and end of life stage needs to be looked at and ways identified to minimize this waste generation and enhance recovery and reuse of resources. Products could be developed which are easier to repair and not difficult to recycle. Implementing a Circular Economy approach would thus be one effective method to ensure this and enable output (including waste generated) of one business/entity/individual to become an input for the other and thus encouraging recovery from waste. While substituting secondary materials for primary materials can offer a part solution, preventing waste and reusing materials, thereby helps in promoting sustainability and resource management. In addition to the environmental pressures brought by the end of life vehicles, the main economic

reasons include the high and volatile commodity prices and potential multi-billion economic benefits from new market opportunities.

If we take the case of Automobile manufacturing, we note that it requires different metals-steel, aluminium, copper, lead, chromium, nickel and zinc, as well as significant amounts of plastic, glass, rubber and fabric. The amount of secondary raw material available indicates the potential reduction in demand for virgin raw materials if the secondary raw material is reused. Analyzing the direct and indirect raw material requirements in the Indian automotive sector during the period 1997–2007, it was found that the material requirement of the sector doubled in a period of 10 years [1]. If current growth trends continue, the total number of registered cars could exceed 100 million by 2030, with a concomitant rise in material requirements. Under business as usual scenario, the total material demand from 2015 to 2030 in the auto sector is expected to increase from 14.1 million tonnes to 102.1 million tonnes [6]. The designing of vehicles for reuse, components for remanufacture, and materials for recycling can close loops and reduce upstream demand for materials and energy. Coupling this with circular business models that focus on product as a service maximize value capture for businesses. Collaboration with the informal sector can create the necessary reverse logistics networks.

Remanufactured parts can be 30–50% less expensive while having the same guarantee and quality control as new parts. Remanufacturing a passenger car engine uses only 23% of the energy used to produce a new engine from raw materials [7]. Businesses that identify ways to close material loops can realize greater profit margins through alternative revenue streams (such as through sale of spare parts) and lower manufacturing costs, Indian companies are starting to recognize these benefits (Refer Box 1).

Box 1: Remanufacturing in auto sector

Tata Motors Prolife, for example, has realized the value of remanufacturing components in their commercial vehicles as these vehicles have long use cycles, are very sensitive to cost increases, and are often managed as a fleet, making the use of remanufactured parts more attractive, especially with a warranty. Tata Motors Prolife buy backs, or exchange, the used vehicle parts such as engine, gearbox, or alternators. The company then remanufactures the returned part and offers the remanufactured product with a warranty. This approach allows longer use of parts, reduces demand for energy and materials, thereby creating new revenue streams for Tata Motors Prolife.

Existing system of end of life vehicle (ELV) recovery in India—A SWOT analysis

In a recent project titled '*Resource Efficiency and Sustainable Management of Secondary Raw Materials*' supported by the German Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB), the authors engaged in an exercise to understand the ELV management system being followed in Delhi.

A vehicle, both commercial and private, is registered for 15 years in India. Some state governments also collect a lifetime of road tax[1] linked to this registration. However, even after the vehicle has reached its end of life, vehicle owners have many options. The owner can continue to run it illegally, sell it to another user[2], keep it parked at free spaces, and/or sell them to a dismantler who operates mostly in the informal sector (without getting to know what happens to its parts and components). Another channel that the consumer could use for getting rid of ELVs is to exchange it with a new vehicle under the buyback option offered by the car dealers.

The government is also working towards a legislation to bring in producer responsibility that would make it mandatory for automakers and their agents to buy old and unroadworthy vehicles and recycle them. The producers could exercise this responsibility with the help of the dealers. This may open another channel where the vehicle owners could go sell their end-of-life vehicles. It is important to note here that in some of the developed countries (for example, in Japan), there is no physical buyback of the vehicles by the producers (OEMs), but these OEMs are responsible for sourcing back of only three revenue-negative components-CFs, airbags, and shredder residues, for which they charge a cess and take help from specialized agencies that collect these components. Figure 1 presents an illustration of the current system of ELV management in India.

The dismantling that takes place in the informal sector is crude and focuses on component reuse which are economically viable. There is also no de-pollution procedure being followed in most of these informal scrap yards, and the hazardous fluids from the ELVs are spilled and disposed of on the ground where the ELVs are handled. In such units, the

[1] It has also been suggested by SIAM that this tax should be discontinued in public interest as it does not serve any major purpose including traceability of the vehicle. We would particularly like to acknowledge some of the valuable inputs received from Captain Mohan Ram, Consultant to TVS Motor Company and Chairman, SIAM Recycling Group which have helped us structure some aspects of the proposed sustainable ELV recovery and management system/business model.

[2] Many of these vehicles (i.e., those that should have been scrapped, as per the government requirement) are instead sold to rural areas or to the second-hand market.

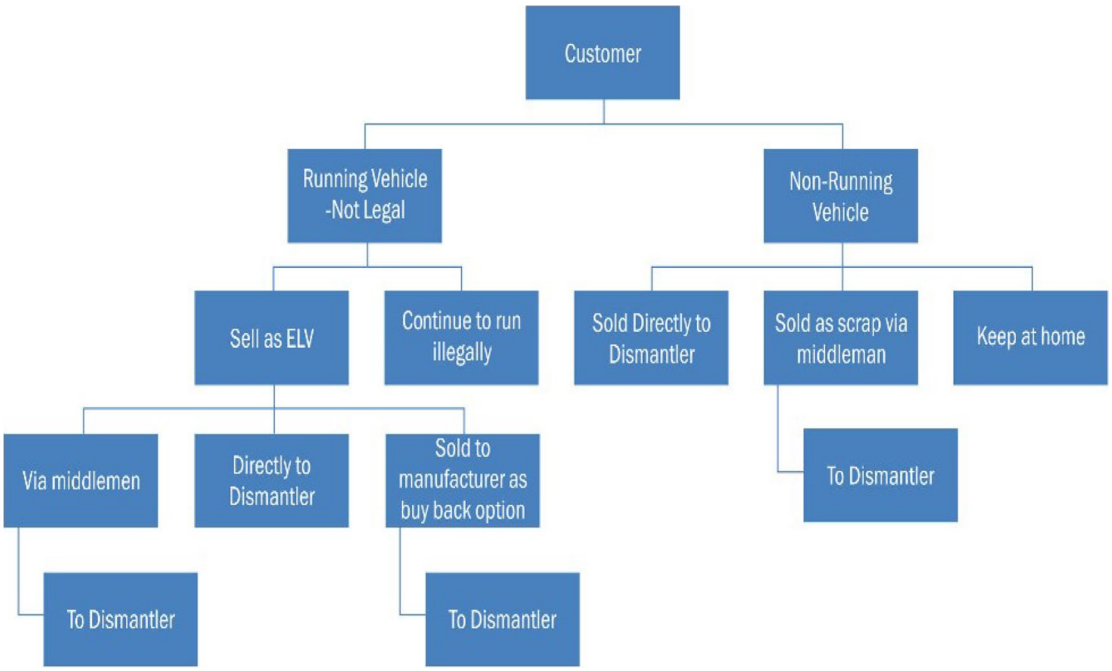

Fig. 1 Existing framework for ELV Management in India. Source: Authors compilation

whole land area is often contaminated with oil, coolants, and other fluids and broken glass is seen all over the area as these material fetch marginal or no value, and there are hardly any storage systems available currently. Gases from the current ELV fleet such as air conditioning refrigerant (AC gas, which is largely R134a) are released into the air generating several occupational safety hazards and environmental hazards as it contributes to global warming. Further having a robust system is crucial as the upcoming fleet uses R1234yf as the new refrigerant which is even more toxic and flammable.

ELVs make their way to the informal sector as it offers a higher salvage price on account of low operating costs. Many of the material resources such as steel that is recovered by the informal sector, is mostly downcycled. A formal set up for steel scrap recycling finds it economically unviable in the absence of requisite scale and quantities. Further, in the absence of advanced cleaner technologies with the informal sector, some materials of high value, such as copper wires and platinum from catalytic converters are not even recovered.

Indian automotive industry has set up voluntary Automotive Industry Standards (AIS 129) for ELVs at authorized centres. These standards try to address some of the concerns and specifically provides a list of materials that should not be used in vehicles. It also lays down the type of information that vehicle manufacturers should make available to the dismantling centres; sets targets for the minimum reuse and recycling or reuse and recovery rates of vehicles; and makes provisions for the type of vehicles with regard to their reusability, recyclability, and recoverability. But in the overall picture of ELV management, these standards could be revised to integrate the concept of circularity and 'closing the loop' aspects of sustainability. What is also required is the development of the AIS 129 standards into a regulatory framework to ensure compliance by the informal sector, where much of the recycling is done.

Moreover, issues over the lack of standard operating procedures, ambiguity in deregistration of vehicles, and poorly informed consumer practices prevent effective and sustainable ELV management. While some aspects of ELV recycling are addressed by vehicular policy, environmental policy, as well as the different wastes management rules in the country, other aspects have not yet been covered by any of these existing legislations. In 2016, the Central Pollution Control Board (CPCB) of India has come out with "Guidelines for Environmentally Sound Management (ESM) of ELVs" with an objective to regulate the sector. These guidelines advocate disposing of ELVs in an environmentally friendly manner and recommend a system of "shared responsibility" involving all stakeholders—the government, manufacturers, recyclers, dealers, insurers, and consumers [8]. Further, the Government of India under the Ministry of Road Transport and Highways is currently drafting a new scrapping policy or end-of-life policy which is expected to provide incentives to the owner of the vehicle for surrendering

an old polluting vehicle and open new avenues for scrap recycling in India.

The authors have tried to evaluate the common strengths, weaknesses, opportunities and threats of the current ELV practices in India based on the existing ELV system. SWOT analysis will enable us to build up on the strengths, address the weaknesses, mitigate the threats and tap the opportunities for supporting a circular economy in the ELV management in India. Table 1 presents the SWOT analysis.

Sustainable ELV recovery and management system/business model: A proposed framework

In this section, the authors propose a framework based on shared responsibility approach for sustainable ELV recovery and management system/business model that can help implement the CPCB guidelines and draws upon the learning from the international practices to build up on the strengths, address the weaknesses, mitigate the threats and tap the opportunities for supporting a circular economy in the ELV management in India. This system, in addition to preserving the environment, focuses on the stakeholder's engagement required in generating economic profitability and social benefits. This paper ideates that the integration of the 6R (reduce, remanufacture, reuse, recover, recycle, and redesign) principles of sustainable manufacturing. The vehicles, parts and components during end-of-life vehicle management, can also be used in the market for repurposing (e.g., electric car batteries used for wind turbine electricity storage), upcycling (e.g., designers producing consumer goods from parts), and down cycling (e.g., shredding and mechanical separations of parts not suitable for any other purpose). Here, the emphasis should be on reuse, considered the most important, in product recovery. Reusing materials/components/ products after its first life cycle in subsequent life cycles of the same product or in other applications, in an effort to reduce the use of new (virgin) raw materials to produce such materials/components/products, needs to be encouraged. But in the current Indian scenario of substandard units, refurbishing worn-out parts and machinery without proper concern for metallurgy, fatigue, or testing can make it a risky proposition to drive vehicles that have these parts. Table 2 presents the integration of the 6R concept in the responsibilities of the different stakeholders in sustainable ELV recovery and management system/business model.

Box 2: 6R principles of sustainable manufacturing

Saman et al. (2012) illustrates (Figure 2) that a 6R framework when applied to the automotive Industry will yield savings both for the manufacturer and the consumer. The authors demonstrate that an elongated use phase of the vehicle not only delays the death of the vehicle but allows the reuse of parts which are in working condition (and do not create any safety issues). Moreover, on effective disposal, recyclable material can re-enter the production territory and assessment against the recovery target is done. In the presence of failure to meet the dismantling target, manufacturers will have to consider redesigning of the vehicle to enable easier and efficient dismantling, thereby enhancing the recovery rate. Easy and simple dismantling will also enhance the recovery of parts which could be used for remanufacturing of vehicles. The saving of energy, labour and raw material, retaining of value and decline in waste will bring down the costs for the consumers [9]. To begin with, the redesigning by the manufacturers can be on a voluntary basis to show-case their commitment to sustainability but overtime once standards and labels are in place redesigning for greater use, refurbishment and remanufacturing can be made mandatory for the manufacturers.

One of the unique advantages of a proper ELV management is that auto components can be refurbished or remanufactured and which can bring significant environmental and economic benefits. The process includes disassembly, cleaning, testing, assembly, processing, and packing, etc. Among developing countries, in recent years China has introduced significant emphasis on the promotion of remanufacturing products from ELVs [10].

In addition, if we look at the experiences of European Union (EU), Japan, Korea, and Taiwan, we note that they have a product oriented legislation to control the recovery of ELVs. These countries have recognized that a distinct ELV law is necessary within the framework of the extended producer responsibility (EPR) framework and have reported success in controlling the number of ELVs off the road. In addition, with the evolving global environmental awareness, shrinkage in the availability of landfill areas, and depletion of natural resources, these countries have designed strategies towards product recovery. Table 3 presents the main highlights of the ELV management system in these countries.

The details in Table 3 have suggested options for designing the framework for ELV management in India and the authors have discussed these with different stakeholders to understand how best and which of these could be contextualized for India.

Table 1 SWOT Analysis of existing ELV management in India. Source: Author's analysis

Strengths	Weakness
National Legislations and Guidelines exist	Weak regulatory framework
CPCB Guidelines on Environmentally Sound Management (ESM) of ELVs for proper handling of ELVs at every stage, setting up of a 'Shared Responsibility' scheme and for the development of an enabling policy framework	Lack of standard definition for ELVs-a-vehicle which at the discretion of its last owner is ready to be scrapped, by the AIS 129; Customers are reluctant to declare their vehicles as ELVs[a], affecting the economic viability of recycling processing units
Automotive Industry Standards for End-of- Life Vehicles (AIS 129) prepared to provide guidance for the collection and dismantling of ELVs by authorized centres and describing provisions that manufacturers should take in order to increase the recyclability of vehicles. Although, this remains an important step towards filing the gap, these standards need to be further developed into a regulatory framework in order to ensure compliance	Absence of regulatory framework linked to CPCB Guidelines and AIS 129 standards prevents compliance by the informal sector, where much of the recycling is done.
Hazardous and Other Wastes (Management and Transboundary Movement) Rules, 2016 that emphasize on the utilization of hazardous and other wastes as a resource or after pre-processing either for co-processing or for any other use	Lack of regulations pertaining to automotive aftermarket to bring in minimum quality and qualification criteria for repair, service and spare parts
Surrendering ELV	Poor Collection network/system including absence of a take back system
Terminal life policy for commercial vehicles along with incentives for replacement for such vehicles	Existing collection network for ELVs is very informal and there is no institutional structure linked to it
Vehicle registration system: All motorised road vehicles in India are tagged with a registration or license number and the vehicle registration plate is issued by the district-level Regional Transport Office (RTO) of respective states. This system can be leveraged for setting up a robust de-registration system	AIS 129 do not provide for a take back system on the part of vehicle producers, resulting in poor logistical arrangement for collection and transportation of ELVs thereby resulting in fragmented recycling hubs
	Low salvage price for ELV offered by the formal sector compared to the informal sector
	Informal ways of recycling leads to low raw material recovery, occupational and safety hazards, environmental pollution and contributes to increased GHG emission
	Limited participation by local authorities, OEMs and dealers in the consumer information campaign elaborating on the need for ELV management
	No Auto shredder facility: Car hulks left after the dismantling process not being processed, implying secondary raw material getting wasted, which otherwise could have been processed in the shredder. Thus, increased percentage of the total ELV mass going into the landfills
	Absence of Information management system: No database (with the RTO) for tracking the number of end of life vehicles and their movement. Some efforts are being made to address this problem. For example the government of India has recently introduced a portal 'VAHAN' which is a national register E-services of registered vehicles. It is proposed that based on the contact details of the last owner of the vehicle, intimation will be sent to the owner with regard to the life of vehicle asking him to surrender the vehicle. A grace period will be provided and in case the vehicle is not deposited to the authorized recycling agency within the stipulated time period, it would be forfeited with penalty

Table 1 (continued)

Threats	Opportunities
Environmental and health threats: No scientific procedures being followed for de-polluting posing serious environmental and health threats	Legislation and Guidelines: Under the Hazardous and other wastes (Management and transboundary movement) rules, 2016, automobile manufacturers could frame the Standard Operating Procedures (SOPs) with respect to recycling of Waste Pneumatic Tyres/ tyre Scrap,, Lead scrap/used lead batteries, Recovery of Tyre Pyrolysis Oil (TPO) from tyre scrap. These SOPs will enhance efficiency in the recycling process
No discussions with respect to post shredder treatment/ technologies leading to increased amount of waste going to landfills. In countries with legislative ELV recycling systems mandate a recycling target of 85% and recovery target of 95% (which includes recycling plus energy recovery (incineration)), ASR treatment is an important process to achieve this. Moreover in absence of recycling/recovery targets, secondary recovery of ASR, Direct ASR-to-energy applications and Thermo-chemical treatment of ASR not being done	As part of the EPR, the manufacturers can also be mandated to design for efficient and ecologically sound recovery of products.. For example, all fluid carrying components in a vehicle can be designed to enable quick and easy removal of all operating fluids, such as oil, fuel, brake fluid and coolant. Or, pyrotechnical components (airbags, belt tensioners, etc.) can be designed so that they can be triggered in a controlled way, using the on board diagnostic interfaces. This can go upto selection of newer materials with similar application possibility but which are easily recyclable as subsititues for currently used difficult to recover and recycle materials
High-investment costs for establishing a reverse-logistics network, costs related to quality-assurance test equipment, and costs linked to complicated dismantling as originally, the product was not designed to be disassembled easily for reuse, remanufacturing, or recycling. These challenges can cause businesses invested in reuse, remanufacturing, and recycling of ELVs to fail	Some existing momentum linked to setting up of scientific and safe dismantling facilities
Huge investment is required for setting up of systemized and environment friendly dismantling units/recycling centers	In 2011, NATRIP facility, which is an automobile dismantling center was setup at Oragadam, near Chennai. It facilitates recycling activities, ensuring that all the recovered material is reused by the auto industry. However this facility needs to be upscaled and similar facilities needed to be setup in different parts of the country
Lack of cooperation between local authorities and other stakeholders	Recently Mahindra Intertrade Ltd, a unit of Mahindra and Mahindra Ltd, has signed an agreement with state-run MSTC Ltd to set up India's first auto shredding facility, which will be equipped with fully automated end-of-life vehicle recycling equipment and innovative ways that will contribute to the efficient recycling of scrapped automobiles. Need to capture interest
	Huge volume of ELVs coming up- Estimates suggest that that more than 8.7 million vehicles have reached the end-of-life phase by 2015. The quantum of resources that could be recovered will make the processing units economically viable
	Huge informal sector
	Presence of a large informal sector engaged in ELV handling and dismantling. Basic Technical know-how and years of experience among informal recyclers, implying with limited training they could be absorbed in the formal setup. Resulting in new permanent jobs
	The large informal sector labour could be tapped for extensive manual dismantling of plastics, glass, aluminium, battery, catalytic converter, copper, electronics in an occupationally and health safety manner that could be an important way to recover some of the high quality materials
	Establishing network of reverse logistics that incorporates informal sector activity would enable capturing material value after use, and prevents health risks for dismantlers. This would also give manufacturers a reliable and economical supply of raw materials
	Zero effect—Zero Defect programme of ACMA: The cluster programme aims at making participating auto component companies globally competitive which would involve leading them to achieve targets of Zero Defect, have environmentally efficient systems and devise mechanism to protect environment for future generations
	Leveraging the opportunity to generate environmental and health protection benefits, informal sector workers can be trained, awareness created and economical access provided for the necessary equipment and technology for the safe and efficient dismantling of the auto components for the end-of-life vehicle management. Doing so will serve the dual objective of addressing the hazardous working conditions prevalent in the informal sector and increasing the cost of informal dismantlers thereby incentivizing environmentally sound and economically viable recycling units to become price competitive
	The strongly increasing demand for raw materials in India should lead to increased prices for raw materials, which would also increase the price of secondary raw material and make future recycling more profitable

Since the opportunity cost of retaining the old vehicle by the owner may not be very high—in fact, the vehicle may serve the owner well in terms of use for shorter distances—many vehicle owners do not discard their unroadworthy vehicles and so these vehicles may never formally reach their end of life. If they do decide to declare their vehicle as redundant, the scrapping allowance they would get by selling the vehicle to the informal sector is more than what they would get from a formal dismantling facility. The reason for this is that the cost of operations in the informal sector (where no occupational and health safety guidelines are followed) is very low as they do not internalize any social and environmental costs

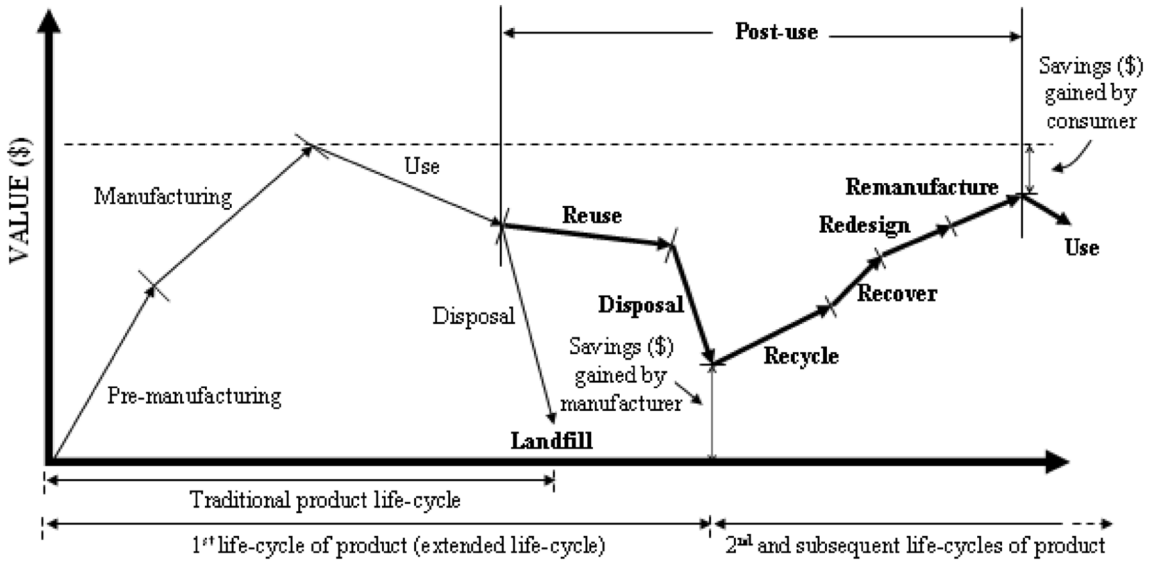

Fig. 2 6R framework applied to the automotive Industry. Source: Saman et al. [9]

Table 2 Integrated 6R within framework for ELV recycling system. Source: Adapted from Azmi et al. [11]

Activity	Responsibility	Explanation
Reduce	Manufacturer	Reduce material variability
Reuse	Part dealers/manufacturer	Sale of reusable parts collected from the dismantling process
Remanufacture	Remanufacturer	Damaged parts which are still usable will be remanufactured by OEM
Recycle	Recyclers	Recycle used materials as raw material for manufacturers/other use
Recover	Incinerator	Regain the energy embedded in the material
Redesign	Manufacturer	Design parts for easier and efficient ELV dismantling

We now elaborate on stakeholders responsibility as part of the proposed framework across the value chain. However, we would like to highlight here that there is need to emphasize for immediate action on de-pollution and recovery of steel in particular. The former is important as the ELVs contain many components that have the potential to cause environmental harm. Oils, fuel, battery acid, coolants, anti-freeze, windscreen wash, and refrigerants (for air conditioning), can all contaminate the earth. If disposed of incorrectly, these fluids can enter the water supply and the food chain, causing a wide range of health problems. There are also other materials that can pose a danger, including switches (some of which contain mercury) and tyres.

The recovery of steel would help in supporting scrap based steel manufacturing in the country. Given the background that India is the world's second-largest importer of scrap steel, behind Turkey, importing around 6 million tonnes a year which are expected to double by 2020, it is important to set up an organized recycling ecosystem supported by regulations which would help reduce dependence on imports. Moreover our estimates suggest that vehicle scrappage when practiced in a formal setup would create a market opportunity of around 2 million tonnes of ferrous scrap to begin with, valuing over 30 billion Indian Rupees. Other materials that have an important potential for recovery are plastics, aluminium and tyres.

Manufacturer responsibility: during the design stage

The increasing change in materials composition (for example, the increase in the fraction of plastic and aluminium) of modern vehicles can create new problems in ELV management. Recycling plastic is very difficult when it is present in small parts or is attached to another material or if the plastic parts are contaminated, e.g., with flame retardants, and if the variety of plastic types is huge. An automobile contains components made from 13 different high quality plastics, although the number may vary slightly across different types of vehicles. However, out of the 13 different types of plastics, 3 types of plastics account for 66% of the applications. These include polypropylene (32%), polyurethane (17%) and polyvinyl chloride (16%).

Table 3 Comparison of ELV management system between countries. Source: Adapted from Ahmed et al. [12], Azmi et al. [11], Directive 2000/53/EC of the European Parliament on end-of life vehicles [13], European Parliament on the implementation of Directive 2000/53/EC on end-of-life vehicles [14], Yi Cho-Hwa et al. [15], Hua-Shan et al. [16], Sakai et al. [17], Ming [18], Chen et al. [19], Chen [20], CLEPA Material Regulation event [21], Solid waste and Recycling Canada [22]

Details	Taiwan	China	Korea	Japan	Canada	Singapore	European Union	India
Government Involvement / ELV Legislation Act	Waste Disposal Act	Statue 307 law on ELV	Law: The act for resource recycling of electronics and automobiles	End of life vehicle recycling law	None (Voluntary)	Vehicle quota system	Law Directive 2000/53/EC Of The European Parliament And Of The Council of 18 September 2000 on end-of life vehicles	No law CPCB guidelines
ELV age	10 years	10 years or 500,000 km	Not specified	Min 3 years, inspection once in 2 years	Not specified	10 + 5 or 10	A vehicle which the holder disposes of or is required to dispose of pursuant in case of failure to comply with emission standards	At the discretion of last owner
Consumer Awareness[a]	Present	–	Present As a part of EPR manufacturer disseminates information	Present	Present	–	Present As a part of EPR manufacturer disseminates information	Not Present
Databases on end-of life vehicles and their treatment	Yes	–	Yes	Yes	Yes	–	Yes	No
Collection system for procuring ELV	Manufacturer responsibility exercised via service stations or car dealers	Collection by designated take back systems operated by dismantlers or service (*OEM*) or vehicle *manufacturers*	Collection agencies/Recycling centres	Manufacturer via Dealership network which then transfers ELVs to the authorized treatment facilities	Automotive Recyclers in Canada (ARC) with the support of the Canadian Vehicle Manufacturers' Association (CVMA)	No manufacturer involvement	Manufacturer and importer responsibility Establishment of ELV collection and recycling network	Largely through the informal sector

Table 3 (continued)

Details	Taiwan	China	Korea	Japan	Canada	Singapore	European Union	India
Recycling fees paid by	Manufacturer and importer when purchased	Market driven (collector pays the last owner)	Market driven (collector pays the last owner)	Deposited by users New vehicles: deposited at time of sale Old vehicles: deposited at time of automobile inspection	Market driven (collector pays the last owner)	Market driven (collector pays the last owner)	Producer ensures free take back of ELVs; In the member states, this was transposed in different ways: From market driven as long as the collector pays the last owner, to fund systems	Market driven (collector pays the last owner)
Recycling centres/ Operator size	303 recycling operators, 5 shredding and sorting plants	367 recycling operators, 1 pilot recycling centre	226 recycling operators, 7 shredding and sorting plants	5000 recycling operators, 140 shredding and sorting plants	–	–	Over 3000; Number varies across member states	Largely by unorganised sector
Effective recovery rate	95%	No target rate Possibility of recycling: 2010: about 85% (material recycling of 80% or more) 2012: about 90% (material recycling of 80% or more) 2017: about 95% (material recycling of 85% or more)	Until 2014: Material + energy recovery: 85% (of which energy recovery rate is within 5%) After 2015: Material + energy recovery: 95% (of which energy recovery rate is within 10%)	95%	–	-	Member States shall take the necessary measures to ensure that operators achieve a reuse + recovery target of 95% and reuse + recycling target of 85% no later than 2015	Llow
Incinerator[b]	Used	Set a developmental goal for energy recovery: Recently started using incinerator (though information not available about its functionality)	Used	Used, Banned landfill dumping of ASR	–	–	Used	NA

[a]Collection and/or disposal fee levied on the owner is taken as a proxy indicator for consumer awareness, where there is no direct information available on whether consumer awareness exists or not

[b]Recycling/ processing ASR for energy recovery is taken as a proxy indicator of incinerator being used

Similarly, recycling aluminium is not straightforward due to its presence mostly in the form of alloys and undifferentiated recycling of all aluminium alloys to cast aluminium leads to downcycling of the wrought aluminium. It is also important to note that the technique of disassembly and recycling will vary across materials. Thus the choice of material is one of the key elements in designing vehicles and will play an important role for sustainable management of ELVs. The main responsibility of the manufacturer during the design stage would include:

- Design for disassembly;
- Adopt material substitution and increase the usage of less-toxic metals and non-metals (such as flame-retardant plastics and PVC);
- Labels identifying materials of various types including plastics should be adhered by the manufacturers and importers of cars; manuals for disassembly should be made available to auto recyclers;
- Have a design for vehicles which is receptive to using recycled/secondary raw material which also reduces chances of downcycling[3]. Specifically, the design could be based on end-of-life criteria while taking into account the age of the vehicle, emission norms, and technology status. In the process, the manufacturer could try getting a competitive advantage by working towards a design that not only optimizes on using resources and dismantability of the vehicle at the end of life, but also that extends the life of the vehicle, thereby delaying its redundancy and death. Extending the life of the vehicle would help create brand loyalty of the consumer towards that vehicle brand and drive up share and profitability of the OEM in the longer run.

Manufacturer responsibility: at the time of sale

Pay a transparent Advance Recycling Fee (ARF) to the ELV fund wherein the fee can be designed within the framework of the following factors:

- Linked to the rating achieved by the vehicle with respect to the index/label for the recovery and recyclability of resources at the end of the vehicle's life and as per the vehicle's class.
- Should cover part (say about 50%) of the rough estimated ELV management cost (excluding the transportation cost of bringing the vehicle from the last user to the dismantling centre). The rest of the cost could be recovered in full or piecemeal from the owner of the vehicle. However, stakeholders could be consulted to arrive at the exact percentage of the price of the vehicle which could be charged as the ARF.

In case the vehicle is being imported, importers and the first owners of the imported vehicles would be liable to pay the Advance recycling fee that will go to the ELV fund.

Dealers' responsibility

Franchised dealers serve as an important channel linking the manufacturer and the buyer of the vehicle. They have significant potential in encouraging the sourcing back of the ELVs and this is the stage at which they can be specifically encouraged to exercise their responsibility for ELV management.

- These dealers could serve an additional function as accredited units that are authorized to collect and recycle vehicles.
- During the sale of a new vehicle, include a guidance document in the vehicle kit that elaborates on the need for ELV management and ways in which the owner/buyer of the automobile could act responsibly when their vehicle reaches its end of life. This document could be prepared by the dealer in consultation with the manufacturer and authorized treatment facilities.

Collect the ELV cess which is levied on the first owner and has to be paid upfront at the time of purchase. The dealer issues a certificate to the first owner (which can be transferred to subsequent owners) for the cess paid and deposits the cess collected into the ELV fund. This cess will later be refunded to the owner when he takes his ELV for deregistration. This will also help dis-incentivize the owner to abandon his vehicle on streets and elsewhere. India does not usually export used vehicles, however, even if such a case arises, ELV cess would be transferred to the concerned PRO or dismantling units depending on the ELV management system in the country concerned to incentivize the last owner to dispose of the vehicle in sustainable manner. For new vehicles that are exported there will be no ARF and ELV cess imposed on producers and owners.

- Enter into an agreement with the owner of the ELV who is exchanging his ELV for the new vehicle whereby the dealer promises to handover the "Certificate of Destruction" and/or "Certificate of Deregistration" to the owner on a postdated basis. In addition, dealers may retain a part of the ELV cess that has to be refunded to the owner as payment for deregistration service provided to the last owner.

[3] Downcycling is also important and may be the only option at times. For example, the presence of copper contaminations in automobile steel only allow to use the steel as construction steel, but not in the automobile industry any more.

- Enter into tie-ups with tow truck operators and offer fee-based services to do an immediate transfer of the ELVs that they have received (in exchange for sale of their new vehicles) to the Regional Transport Offices (RTO) or to any authorized treatment facility, whichever is convenient.

Last owner's responsibility

The last car owners (i.e., users) are the starting point of the ELV chain and should have the responsibility to ensure that the vehicle gets deregistered. The various channels that could be explored for this are:

- Surrendering the car at the RTO

  The owner takes the ELV to the RTO (which later sends the vehicle to an authorized treatment facility), that is also authorized to act as a designated collection point. The RTO then legally issues a "Certificate of Destruction" and/or "Certificate of Deregistration" with all the paperwork related to the surrendering of the car being completed on its premises. These collection points are at the customer front end and there would be such multiple points in a metro city. The deregistration should be mandatory and is necessary for ensuring transparent and effective steering of ELVs into the ELV formal system. Based on the rate list that is published by the RTO, the owner gets paid a price for the ELV. This rate list could be arrived at by consulting the vehicle manufacturers, and focusing on the revenue streams, and cost flows which suit the target value of the recycling process. The rate list should also have a differentiated element linked to the condition of the cars and the extent of usable parts (that can be assessed after an inspection of the vehicle's physical condition). However, it is important to make a distinction here between the rate list for vehicles which are already plying on roads (and do not have any advance recycling fees deposited against them into the ELV fund) and those which will be sold once this proposed framework gets implemented (in which case, for all new vehicles sold, there would be an advance recycling fees collected at the time of sale of the vehicle, in part paid by the manufacturer when he sells to the dealer and in part paid by the buyer of the vehicle is purchased from the dealer). This will be a way to exercise the shared responsibility.

- Surrendering the car at the dealer's in exchange for a new car

  The owner takes the ELV vehicle to the vehicle dealer from whom he is buying a new vehicle and exchanges his old vehicle for the new vehicle. The dealer promises to handover a "Certificate of Destruction" and/or a "Certificate of Deregistration" to the owner on a postdated basis (since the dealer has to get the certificate issued from the RTO or an authorized treatment facility after surrendering the car there). For example, this certificate can be handed over to the owner when he comes back to the dealer for his first service. The salvage price[4] of the ELV is adjusted in the price of the new car which the owner is buying in exchange of his ELV. The RTO then sends the car to the authorized treatment facility.

The proposed business model (as shown in Fig. 3) would also address the issue of rising number of abandoned vehicles. These include vehicles which are either unclaimed (i.e. damaged during accidents, caught in illegal act) and those which are not in use and also continue to occupy huge space on road contributing to traffic congestion and parking issues across the cities. This will be done through two ways. First in the absence of sustainable ELV management system authorities have not been able to do anything to address the issue. However, once formal ELV dismantling takes off, authorities would be in a position to start auctioning these vehicles to ATFs which would help in tracking the vehicles going to formal treatment facilities. Moreover, competitive bids would work towards lowering the per unit cost of recycling at the same time providing better prices to the last owner and making scrap recycling economically viable. Second, the first owner pays an ELV cess which is refundable to the last owner subject to de-registration. For the ELV cess, first owner gets a certificate which is transferable on sale of his vehicle to the next owner. Both ARF and ELV cess contributes to ELV fund which is then used for setting up requisite infrastructure. ELV cess gets refunded from the ELV fund, which shall be managed by non-governmental body such as Automotive Recycling Promotion Centre.

Moreover, at the time of the purchase of a new car, the buyer/first owner of the vehicle can also be made to pay an

[4] The salvage price that is which is globally offered to the owner to pay the cost of vehicle's steel. For bringing about a behavioral change in Indian consumers, a markup over the price of steel could be considered. The suggested additional responsibility of the RTO as a collector in our proposed framework (Fig. 3) is a short-term measure that will help in giving impetus to the whole process of formal ELV management by providing people with a convenient option to go to and surrender their vehicles. But in the long run, as in most EU member states, vehicle manufacturers and importers should be made responsible for setting-up national collection networks for the collection of all ELVs. In collective schemes, a Producer Responsibility Organization (PRO) could be set to implement the EPR principle on behalf of all adhering companies (the obligated industry). These PRO could provide take back systems for effectively implementing EPR principles. In the Indian context, manufacturers could exercise their responsibility via dealers.

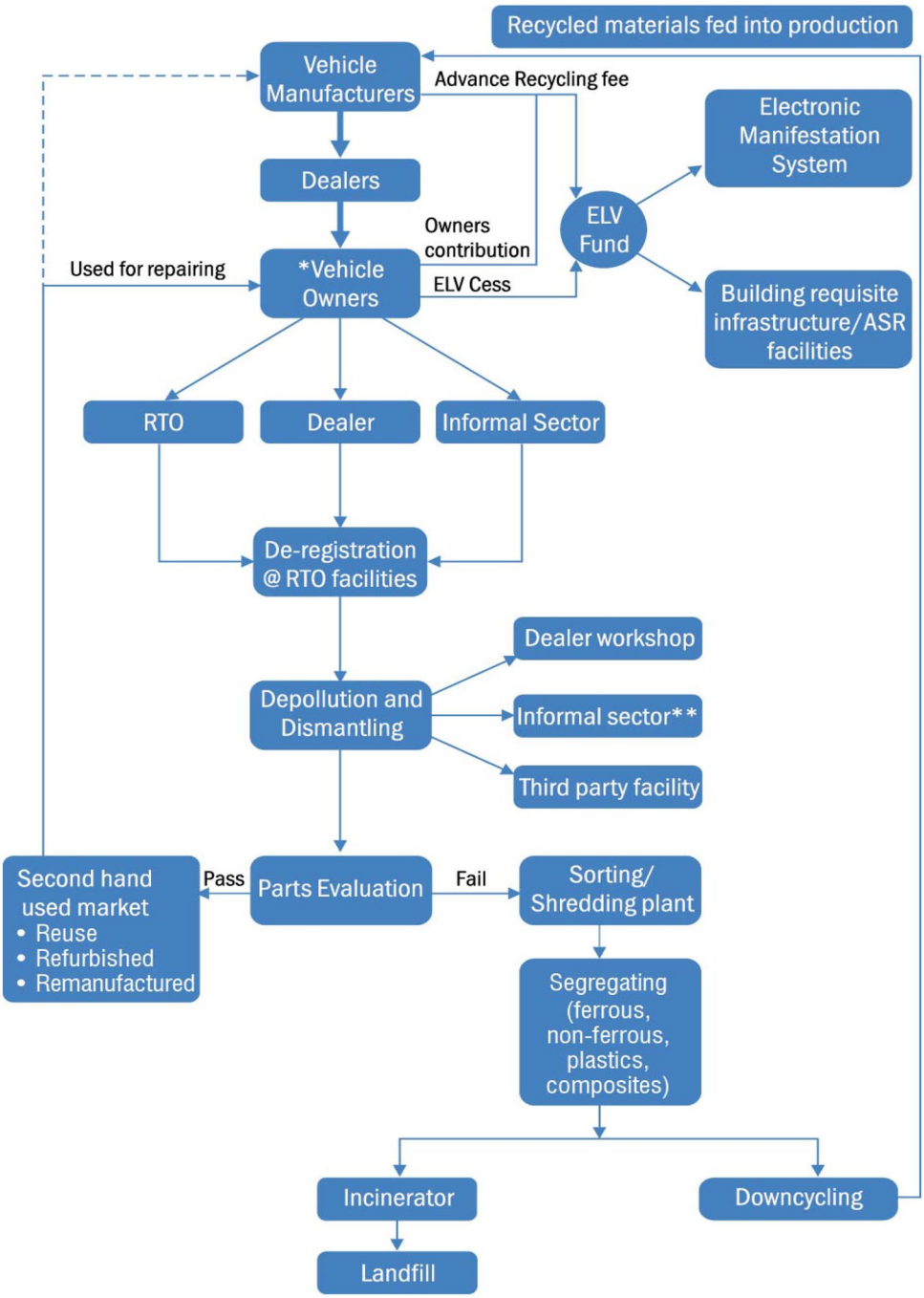

Fig. 3 Proposed framework for Sustainable ELV Management. Source: Developed by Authors

ARF. So it is important to note that in our suggested framework, both the manufacturer and first owner contribute their share to the advance recycling fee.

Authorized treatment facility (ATF) Operators responsibility

The facility will have the capacity for proper de-pollution of fluids, batteries, pyrotechnics, liquid petrol gas tanks. The main purpose of the depollution is to remove all hazardous materials from the vehicle and safely dispose of them. It is important to highlight here that the ELVs may at times have certain reusable parts such as glass, plastics (bumpers), tyres, catalytic converters. These parts can be separated at the depollution unit and can be sold out in retails or can also be used by part dealers [23].

ATFs—more commonly referred to as dismantlers, scrap yards, salvage yards, or breakers yards—are sites that have been licensed to accept waste motor vehicles, store it till the vehicles are dismantled and then undertake the dismantling,

recycling, and treatment process complying with the requirements of the ELV regulations.

The facility needs to ensure there is optimal dismantling done prior to shredding with the goal of increasing materials recovery, reducing shredder residue volumes, and reducing contaminants. Specifically, the dismantling needs to:

- Increase the number and amount of materials and parts that can be removed;
- Source the recovered parts to a market for reuse;
- Sort, save, and send defective and damaged parts for recycling;
- Recover automotive fluids from defective and damaged parts and send them for recycling.

Dismantling can enable the recovery of up to roughly 40% of the total ELV weight for reuse as spare parts and for recycling of large metal and plastic components. Some of the liquids and parts from the depollution stage can also be reused, for example, fuel. Other parts, such as engines, batteries, and electronic components are potentially reusable depending on their age and state of repair. Electric and electronic components can be recycled together with electronic waste. In some cases, materials of high value, such as copper wires and platinum from catalytic converters are also collected prior to shredding. Currently, in the absence of advanced cleaner technologies with the informal sector, many of these high value materials from vehicle electronics are not recovered. Some of these materials may be simply discarded if they do not fetch value in the market. However, with formal dismantling process in function and the setting up of ATFs, these materials will start getting recovered.

Post dismantling, the parts which are not fit for reuse or remanufacturing are sent to a shredding plant. The purpose of shredding is to segregate materials for recycling. Plastics and glass would be segregated prior to shredding treatment. The leftover material is first shredded in a few square inch sizes and then segregated as iron, aluminum, copper, plastics, glass, and other forms. With up to 90% of the ELV weight being shredded, post shredder sorting is a crucial process to recycle and recover materials. After the shredding process, dense media can be separated from the light ASR, or Shredder Light Fraction (SLF), using an air classifier. Magnetic separation can then be used to remove the ferrous fraction, non-ferrous materials, and "auto shredder residue" Materials that can be recycled are then sent to manufacturers. The remaining light and heavy ASR fractions are then sent to energy recovery and landfills. Box 3 suggests two ways in which a treatment facility can be structured.

Box 3: ways in which a treatment facility can be structured

Options for structuring the Authorized Treatment Facility (ATF)

Option 1: One comprehensive facility covering a certain geographical area such as a city or for a group of cities/towns which has a depolluting unit, dismantling facility, recycling space, and shredding machinery all in one place. In the current situation in Indian cities, this facility will need to come up. Third-party involvement could play an important role in setting up the facility.

Option 2: ATF could have segments spread across a geographical area such as a city or for a group of cities/towns with close connects and tie-ups. These tie-ups also need to integrate the informal sector such as the Mayapuri in North Delhi. Additionally, this structure could explore the possibility of carrying out dismantling at the various large vehicle service stations/workshops that are spread across the cities. After the dismantling, dealers will have reusable parts, which they can either sent to the manufacturer and/or retain some parts and use it for servicing and repairing works and/or sell them in the secondary market.

In the immediate short run, the ATF and the informal sector will continue to operate in parallel. ATF facility which has a depolluting unit, dismantling facility, recycling space, and shredding machinery all in one place, will take time to set up and have a good geographical spread and coverage. But with millions of informal labourers being involved in the ELV management it is important not to siphon off the informal sector, and instead leverage their network for operationalizing the formal setup. To give an example, the current informal sector could act as an important collection point in the formal set up. Further, with increased awareness regarding the occupational and health safety hazards of operating in a crude way and proper capacity development of these workers, their recognition of benefits and options of formal employment would become more lucrative for these informal workers. Their work efficiency would also improve enabling higher recovery rates from the ELVs and generating environmental benefits for the society in terms of reduction of pollution.

It is important to highlight here that the National Automotive Testing and R&D Infrastructure Project (NATRIP) facilities is the first vehicle recycling and dismantling demonstration centre was setup at the site of Global Automotive Research Centre (GARC). This initiative requires scaling up for adoption of world-class technologies supporting

sustainable management of End-of-life vehicles. NATRIP facilities and would also be crucial for training personnel who could then engage in scientific dismantling and work at the ATFs thereby leading to better resource recovery [24].

Institutional support required from the government

a. Defining ELVs:

One fundamental impediment gets reflected in the way ELVs are defined and for this it is extremely important to have objective criteria for the same. In absence of a robust PUC system and spurious practices manipulating with the number of kilometers vehicles has been driven, age criteria perhaps can bring greater clarity and would suffice the requirement to meet the ever tightening emission norms. This would also be helpful when government needs to incentivize declaration of ELVs and disposing off old fuel guzzling and polluting vehicles. Moreover, it also addresses the concerns of stakeholders over economic viability of operating shredder facility as they can assess the number of vehicles available for scrapping. Comparison of ELV management system across countries as shown in Table 3 highlights that countries keeping a age criteria for defining ELV are using the range of 10–15 years, as during such a lifespan technological advances/up-gradation is available to reduce emissions.

In the long run end-of-life criteria could be defined using combination of 2 factors- the age of the vehicle (say greater than 10 years) and the road worthiness (PUC + testing for road safety) of the vehicle. So for a vehicle which is more than 10 years old and has failed the road worthiness test twice consecutively, then it should be declared as an ELV. However, if a vehicle which is less than 10 years old but has failed the road worthiness test twice should be subject to deeper investigation to identify the reasons for failure [25] .

b. Encouraging declaration of ELV:

Make it mandatory to obtain a 'Certificate of destruction', which certifies that the owner has brought his ELV for de-registration. This will remain a pre-requisite for getting ELV cess refunded. Once the car reaches its end of life and it does not get deregistered, the vehicle owner faces a penalty. Random checks by the transport policy officials can be used to assign credibility to the levying of penalty. For existing ELVs, RTOs can also notify the vehicle owners to get their ELVs deregistered. To incentivise the declaration of ELVs, refund of ELV cess to the last owner could be linked to deregistration. The name of the current vehicle owner should be recorded in the register, even at times of (temporary) de-registration.

Increasing road tax on re-registration of vehicles, disincentivising re-registration when the vehicle is close to its end of life.

The RTO database overtime can also be strengthened to create a mapping of vehicles with its owners and ensuring that the owners have disposed off their old vehicles (which have reached their end of life) before they have bought their new vehicles.

a. Designated collection points: regional transport offices (RTOs) should be allowed to also operate as Designated Collection Points that legally issues a "Certificate of Destruction" and/or 'Certificate of Deregistration' and then transfers them to accredited dismantling facilities or authorized treatment facility and/or manufacturer owned and operated collection and treatment facilities. The cost of the logistics could be borne out of the ELV fund. Over time, vehicle manufacturers could be mandated to set up collection facilities
b. Infrastructure support: Land for setting up requisite infrastructure including auto shredder facilities. Here, Government could initially waive off the rental for few initial years, and overtime when the facility becomes economically viable, reasonable/ market rent could be laid. The current informal sector engaged in the ELV management could be relocated to this land, away from the residential areas and having to meet the minimum hygiene standards such as the impervious floor detailed in AIS129.
c. Setting up of Automotive Recycling Promotion Centre (ARPC): This needs to be a nongovernmental body which acts as regulator as well as an auditor for ELV recycling operators. This body also manages the ELV Fund; they are required to provide monetary incentive (refunding ELV cess) for owners who wish to surrender their vehicle for scrapping. It also monitors the functioning of electronic manifestation system which helps in regulating by keeping a record of ELV movement (buying/selling) at various stages—when a vehicle gets deregistered, where is it depolluted, where it gets dismantled and so on. Even the small (informal) dismantlers need to have the vehicle de-registered before initiating the dismantling process.

ARPC would develop an overall index/label indicating the recovery and recyclability of resources at the end of life of the vehicle.

At this point, it is important to note that the managing of ELV fund will be a challenging task and ARPC will need to be careful in performing this task. The money from the ELV fund will need to be used for different purposes as discussed in this paper. One other purpose for which the money

from the ELV fund could be used is strengthening of the enforcement measures to ensure that the ELVs create the needed flow of ELVs to the designated collection points. How much would the contribution to the ELV fund from different stakeholders and the utilization of the same for different purposes is a potential area of research, and the authors have not included the same within the scope of this paper.

d. Benchmarks/certification/labeling/targets:

   Quality standard for secondary raw material will help in creating the market for secondary resources. These standards could also be accompanied with a warranty that would ensure the consumers of the quality of the material.

   Further such standards could be used to develop efficiency targets which require the use of a certain percentage of recyclates and recyclable materials in new cars as part of a shift to emphasizing design for the environment.

   Set up strict quantified targets to be achieved by the recyclers for reuse, recycling and recovery of ELV

   Setting up minimum benchmark requirements that informal sector needs to follow for carrying operation (safe disposal of toxic gases, oils, glass, puncturing the engine if the vehicle has reached its ELV, health and safety needs of the informal sector). Moreover, designing social security incentives for informal labourers could be considered. This internalization of social and environmental costs will then increase the cost of operations of the informal sector and prevent them from offering a relatively higher price than the formal sector for the ELV

   Ban materials such as tires, windshield glass and polypropylene plastic going into the landfills, and/or impose high taxes on landfilled shredder residue to ensure that recycling targets are met and there is minimization of shredder residue

e. Awareness generation: There needs to be emphasized awareness created for the labourers about the adverse health outcomes if they continue to operate in the crude manner. Abiding by the occupational and health safety standards will increase the cost of operations of the informal sector and they may not then be able to offer the relatively high prices they currently do to the last owner for retiring their old vehicles. But this would certainly help bolster our efforts towards integrating the informal sector into a formal set generating social and economic benefits for them in addition to creating environmental benefits for the society in terms of reduction of pollution generated through their informal ways of operation and ensuring higher recovery rate of resources from the ELVs.

f. Enforcement through effective action to reduce illegal dismantling of ELVs at dealers and repair shops and improve ATF compliance; enforcement against illegal ELV exports from the country

g. Encouraging design for disassembly and recoverability: Government can integrate design for disassembly and recoverability as a part of the Extended producer Responsibility as outlined in the EU. Standards can be developed by competent authorities for disassembly which can be incorporated as part of the relevant legislature. Further, this legislation could be made enforceable by linking it to the registration process. In other words, a vehicle can only be registered in the name of a buyer only if these standards are adhered by the OEMs of the vehicle. Further distribution channel partner certification or registration to the dealer can be provided by the government only if the person signs a letter of undertaking that the person will sell vehicles that comply with the set government norms and standards for disassembly and recoverability by the OEMs.

Addressing of weaknesses and threats faced by the current ELV management through the proposed framework

In this section, we present a mapping of addressal of weaknesses and threats faced by the current ELV management system in India through the proposed shared responsibility based framework for ELV management in India (Table 4).

Conclusion

One of the major issues that the world is currently grappling with is the unprecedented growth in the demand for various resources and the associated challenge in meeting the demand. Not only is the resource requirement in the making of automobiles significant, but also it is also the potential for recovery of resources for vehicles that are at their end of life. ELV management is important not only because it is a potential source of supply for secondary raw materials, but is also a major step towards reducing carbon footprint. With the government moving towards stringent emission norms, there would be a need to create better and frequent advancements in ELV management. Efficient resource recovery and recycling from ELV may not guarantee that these resources are recycled back in the same sector. Nevertheless, it will find significant application in other sectors such as infrastructure, which will help in reducing the use of virgin resources in the economy.

Table 4 Addressing of weaknesses and threats faced by the current ELV management through the proposed framework

Weakness and Threats facing the current ELV management in India	Proposed solution in the shared responsibility based framework	Stakeholder responsible
Lack of standard definition for ELVs	Defining objective criteria is required for effectively managing the current fleet of end of life vehicles. In absence of a robust PUC system and spurious practices manipulating with the number of kilometers vehicles has been driven, age criteria perhaps can bring greater clarity and would suffice the requirement to meet the ever tightening emission norms	Government
Poor Collection network	In the short run last owners can surrender their ELV to RTO, dealers however as in most EU member states, vehicle manufacturers and importers should be made responsible for setting-up national collection networks for the collection of all ELVs	Manufacturer, Dealers, Government (acting through designated collection points; RTO)
Low recovery rate	Design for disassembly and recoverability (so that the components and materials can be easily recovered, reused, remanufactured, refurbished or recycled); manufacturers and importers of cars should label parts and provide SOPs for dismantlers	Manufacturer, Government (through linking registration of a vehicle to it being designed for disassembly)
	Dismantling for reuse, sorting defective parts and ensure recycling	Dismantlers (ATF operators)
	Setting recovery targets, regulations for dismantling and viability gap funding for supporting recycling facilities	Government
Tracking of ELVs	Mandatory to get certificate of destruction from legal ATF as prerequisite for de-registration	Last owner
	ELV manifestation system which tracks ELV movement at stages of deregistration, depollution, dismantling and recycling	Government (via Automotive recycling promotion centre)
Environment and health hazards	Adopt material substitution and increase the usage of less-toxic metals	Manufacturer
	Setting up minimum benchmark requirements that informal sector needs to follow for carrying operation (safe disposal of toxic gases, oils, glass, puncturing the engine if the vehicle has reached its ELV, health and safety needs of the informal sector). Moreover designing social security incentives for informal laborers could be considered. This would also help in internalizing the social and environmental costs in the operations cost of the informal sector and reduce the price difference that exists in the salvage prices offered by the formal and informal sector	Government
	Prepare an exhaustive list of all materials that should be banned from getting dumped in the landfill including both that may be hazardous and could impact health of people and environment; and those that may not be hazardous, but have potential for recovery, thereby enhancing resource efficiency. This will create recycling opportunities	
Huge investment acting as a deterrent	Contribute ARF to ELV fund	Manufacturer
	Collects ELV cess and part of ARF from the consumer and deposit the same in ELV fund	Owner, Dealers
	Viability gap funding for supporting recycling facilities	Government
Lack of cooperation among stakeholders	ARPC acting as a regulator and auditor for ELV recycling operators, salvage price to last owner, monitors functioning of electronic manifestation system, develop index/ label indicating recyclability of ELV	Government (via Automotive recycling promotion centre; ARPC)

Table 4 (continued)

Weakness and Threats facing the current ELV management in India	Proposed solution in the shared responsibility based framework	Stakeholder responsible
Encouraging use of SRM	Design receptive to use recycled/SRM raw material	Manufacturer
	Quality standard for secondary raw material will help in creating the market for secondary resources. Further mandating the use of a certain percentage of recyclates and recyclables materials in new cars as part of a shift to emphasizing design for the environment	Government
Low Consumer Awareness on account of ELV management	At the point of sale of, include a guidance document in the vehicle kit that elaborates on the need for ELV management and ways in which the owner/buyer of the automobile could act responsibly when their vehicle reaches its end of life	Dealers

Source: Developed by the authors

Central Pollution Control Board estimates suggest that 21 million vehicles will reach their end-of-life by 2025. A recent study by the International Energy Agency (IEA), shows that the passenger car ownership in India is expected to grow by 775 per cent over the next 24 years. The study adds that the number of vehicles will grow from the current 20 per 1,000 inhabitants to 175 [26].

With the government eyeing large-scale implementation of National Electric Mobility Mission 2020, ELV management system needs to evolve given the recent push by the government towards electric mobility and will need to be aligned with the technological developments.

With the introduction of hybrid cars in the Indian market, effective end of life management practices can prove extremely beneficial towards recovery of newer materials such as rare earths. It is estimated that many of the mild and strong hybrid that was launched few years ago, will reach their end of life in the years ahead. Since, India is completely import dependent for rare earths elements, hence efficient recovery and recycling would not only help in reducing future imports, but also provide material security in the long term. Japan, for example, another country with almost 100 percent import dependent for rare earths, has already rolled out plans for rare earth element recoveries from end of life hybrid vehicle components. It is estimated that between 2010 and 2030, the potential for recovery of REEs largely from hybrid transmission and nickel metal hydride battery has been estimated at 220 tons and 2900 tons [27].

Though electric vehicles have less than 20 parts vis-à-vis conventional ICE based vehicle which has around 2000 parts, there is need to ensure high-grade recycling capacity with the aim of recovering lithium, cobalt, and other metals used in traction batteries which is important from an ecological and industry-specific point of view. A shared responsibility based framework for ELV management in India can contribute to increasing overall resource efficiency and environmental performance in India without harming the competitiveness of its automobile industry.

References

1. IGEP (2013) India's Future Needs for Resources. Dimensions, Challenges and Possible Solutions: http://www.igep.in/live/hrdpmp/hrdpmaster/igep/content/e48745/e50194/e58089/ResourceEfficiency_ Report_Final.pdf. Accessed 3 Mar 2018
2. Economic Times (2016) Vehicle policy to generate steel scrap worth Rs 11,000 crore per annum Retrieved from: https://www.economictimes.indiatimes.com/articleshow/52598995.cms?utm_source=contentofinterest&utm_medium=text&utm_campaign=cppst. Accessed 26 Apr 2018
3. SIAM (2015) Automotive Production Trends. Society of Indian Automobile Manufacturers. Available at: http://www.siamindia.

com/statistics.aspx?mpgid=8&pgidtrail=13. Accessed 3 Mar 2018
4. Akolkar AB, Sharma M, Puri M, Chaturvedi B, Mehra G, Bhardwaj S, Mutz D, Arora R, Saluja M (2015) The Story of Dying Car in India. Part II. Report prepared on behalf of GIZ, CPCB and Chintan. New Delhi: CPCB. Available at: http://cpcb.nic.in/upload/Latest/Latest_113_Draft_Guidelines_ELV-1_.pdf
5. UNEP (2016) Global material flows and resource productivity. In: An Assessment Study of the UNEP International Resource Panel. Paris, United Nations Environment Programme
6. TERI-GIZ-DA (2016) Material consumption patterns in India: a baseline study of the automotive and construction sectors. Available at: https://www.international-climate-initiative.com/fileadmin/Dokumente/2016/GIZBaselineReportSummary_SinglePages.pdf. Accessed 3 Mar 2018
7. Ellen MacArthur F (2016) Circular Economy in India: Rethinking growth for long-term prosperity, 2016, http://www.ellenmacarthurfoundation.org/publications/. Accessed 3 Mar 2018
8. Central Pollution Control Board (CPCB) Guidelines for Environmentally Sound Management of End-of- LIFE Vehicles (ELVs) 2016. Available at http://cpcb.nic.in/Final_ Report_on_ELV_Guidelines_December_2016.pdf. Accessed 3 Mar 2018
9. Saman MZM, Zakuan N, Blount G (2012) Design for end-of-life value framework for vehicles design and development process. J Sustain Dev 5:95–111
10. Li J, Yu K, Gao P (2014) Recycling and pollution control of the End of Life Vehicles in China. J Mater Cycles Waste Manag 16:31. https://doi.org/10.1007/s10163-013-0226-6
11. Azmi M, Saman MZM, Sharif S, Zakuan N, Mahmood S (2013) Proposed framework for End-Of-Life Vehicle Recycling System Implementation in Malaysia'. In: Paper presented at the 11th Global Conference on Sustainable Manufacturing, Berlin
12. Ahmed S, Ahmed SH, Shumon MRH, Quader MA (2014) End-of- life vehicles (ELVs) management and future transformation in Malaysia. J Appl Sci Agric 9(18):227–237
13. Directive 2000/53/EC of the European Parliament and of the Council of 18 September 2000 on end-of life vehicles—Commission Statements Official Journal L 269, 21/10/2000 P. 0034–0043 (2000) Retrieved from: http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex:32000L0053. Accessed 3 Mar 2018
14. Report from the Commission to the Council and the European Parliament on the implementation of Directive (2000) 53/EC on end-of-life vehicles for the period 2002–2005 {COM(2007) 618 final}/*SEC/2007/1348 final*/Available at: http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52007SC1348. Accessed 3 Mar 2018
15. Yi C-H, Park JW (2015) Design and Implementation of an End-of-Life Vehicle Recycling Center based on IoT (Internet of Things) in Korea. Retrieved from: http://www.sciencedirect.com/science/article/pii/S2212827115000463#. Accessed 26 Apr 2018
16. Hua-Shan T, Wei-Hsiung H (2015) An exploration of deriving fuel from end-of-life vehicle automotive shredder residue. J Chin Inst Eng Vol. https://www.researchgate.net/journal/0253-3839_Journal-Chinese_Institute_of_Engineers. Accessed 3 Mar 2018
17. Sakai S, Yoshida H, Hiratsuka J et al (2014) An international comparative study of end-of-life vehicle (ELV) recycling systems. J Mater Cycles Waste Manag 16:1–20. https://doi.org/10.1007/s10163-013-0173-2
18. Ming C (2012) Automotive Product Recycling Industry in China. Retrieved from: http://www.maara.com.my/uploads/1/2/6/1/12610322/automotive_product_recycling_industry_in_china_20121128.pdf. Accessed 3 Mar 2018
19. Chen KC, Huang SH, Lian IW (2010) The development and prospects of the end-of-life vehicle recycling system in Taiwan. Article in HYPERLINK https://www.researchgate.net/journal/1879-2456_Waste_ManagementWasteManagement 30(8–9):1661–1669 https://doi.org/10.1016/j.wasman.2010.03.015. Accessed 3 Mar 2018
20. Chen M (2005) End-of-life vehicle recycling in China. Now Future 57:20. https://doi.org/10.1007/s11837-005-0146-6
21. CLEPA Material Regulation event (2016) Retrieved from: http://clepa.eu/wp-content/uploads/2016/04/8.-Asian-ELV-status.pdf. Accessed 3 Mar 2018
22. Solid W, Recycling Canada (2016) Building a circular economy for end-of-life vehicles (ELV) in Canada. Retrieved from: http://www.solidwastemag.com/news/building-a-circular-economy-for-end-of-life-vehicles-elv-in-/
23. Arora N (2017) Engineer the End. *Down to Earth Magazine*, Centre for science and environment. Available at http://www.downtoearth.org.in/news/engineer-the-end-56721. Accessed 3 Mar 2018
24. NATRiP (2015) National Automotive Testing and R&D Infrastructure Project homepage: http://www.natrip.in
25. Datta MJKA, Sitalakshmi. C, Sharma S, Loung A, Banerjee A (2017) Improving Inspection and Maintenance for In-Use Vehicles in India. The Energy and Resources Institute, New Delhi
26. IEA (2015) Energy and climate change: world energy outlook special report. International Energy Agency, New Delhi
27. Yano J, Muroi T, Sakai (2017) Rare earth element recovery potentials from end-of-life hybrid electric vehicle components in 2010–2030. J Mater Cycles Waste Mana 18(4):655–664