What are the Best Practices for End-of-Life Vehicle Management? A Practical Assessment of Estimates, Perceptions, and Policies

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ABSTRACT

Purpose: The primary purpose of the present research is to assess the people's awareness level of End-of-Life Vehicle (ELV) management in India. The study proposes to estimate the projected annual demand for the new ELVs over 15 years from 2020 – 2035 and assess the growth rate in new annual ELVs.

Design/Methodology/Approach: Employing a mixed method study, we obtained secondary data from the annual reports from the Society of Indian Automobile Manufacturers (SIAM). In Study 1, we employed Log-Linear regression and Compounded Annual Growth Rate (CAGR) to compute the growth rates for these projections. After that, we collected the primary data of vehicle users (n=920) using survey methodology, both open and closed-ended items completed the test battery (Study 2A and 2B). While open-ended items were analyzed qualitatively, the closed-ended items were analyzed quantitatively.

Findings: The estimation of annual ELV estimates and their cumulative figures over 15 years determined the market size in the future, outlining the importance of ELV management. The qualitative approach helped deduce the people's most prominent sentiments regarding decommissioning and the ELV management process. From the primary analysis, we concluded that people perceived the ELV management process positively; however, there are areas where the government's specific attention is warranted.

Originality: In this study, we have outlined how specific measures in ELV management can result in a sustainable circular economy. Additionally, we have designed a test battery to understand people's perception, which is first of its kind effort to understand what people think about ELV management. Studies globally considering people's perception of ELV can employ the test battery designed for this study. Additionally, countries that have ELV management in nascent stages can refer to India's experience with ELV management and the related people's perception.

Keywords: End of Life (ELV) Management, Pollution; Scraping; Government of India; Perception; Policy

1. Introduction

The old and used vehicles are assessed based on their efficiency and detrimental environmental effects. The old vehicles are dismantled or left alone based on such an assessment. If the vehicles are dismantled and scrapped, the resulting scrappage must be further processed for recycling or reuse. Recycling or reusing resources can promote environmental conservation, advance technology, and encourage a circular economy (Arora *et al.*, 2019; Molla *et al.*, 2022; Saidani *et al.*, 2018; Tian and Chen, 2014). Those vehicles that have become unusable and unworkable and are ready to be scrapped are called End of Life Vehicles (ELVs). No less than 25 million vehicles come to their end of life annually across the globe, which only increases as the number of vehicles on the roads increases yearly (Jody *et al.*, 2011), with China accounting for the highest number (Han *et al.*, 2019). The whole process of assessment, dismantling, and handling the subsequent scrappage comes under the aegis of ELV management. Earlier, ELV management was considered significant for economic and technological reasons, but today it has become all the more relevant for environmental causes (Kanari *et al.*, 2003). Around 85% of the waste from the dismantling process is recyclable and recovered (Rosa and Terzi, 2018). The ELV management has recently taken a unique transformation as it provides a legal waste collection and disposal system (Wei and Dou, 2022). This waste estimation aids in evaluating other automobile wastes, including car batteries, tires, and other parts (Andersen *et al.*, 2008). However, ELV management has not been scientifically explored in many countries, leading to deficient or no policy (Saidani *et al.*, 2018).

Drawing attention to India, the increasing number of old vehicles has contributed to a steady increase in air pollution, particularly in prominent metropolitan cities (Badami, 2005; Chandrappa and Chandra Kulshrestha, 2016). Light Commercial vehicles (LCVs, viz., taxis, cabs, and auto-rickshaws) (MoRTH, 2018) contribute to nearly 65-70% of India's vehicular pollution. Older LCVs manufactured before 2000 constitute less than 1% of the entire LCVs, contributing 15% to the total vehicular pollution (MoRTH, 2018)). Older vehicles have lower fuel efficiency, higher fuel consumption per km, and higher emissions (MoRTH, 2018), and the unregulated recycling of ELVs only adds to the problem (Krishna et al., 2018). ELVs form the single most considerable hazardous waste coming from households. Such waste generation category is difficult due to the structure's complexity and varied composition of the vehicle flow (Karagoz *et al.*, 2020).

Millions of ELVs run on the roads in prominent pockets and are parked along the roadside. Therefore, the regulation of ELV management through legislation in India is a decision in the right earnest; however, the public's education about the same remains desired. Therefore, this research study's primary purpose is to assess the people's awareness level in general about ELV management in India. This research focuses on reporting the detrimental effects of old vehicles on the environment and the specific benefits that society and industry can derive from ELV management. The second purpose of the paper is to provide a critical review of the current situation in ELV management policy-making in India that can be replicated in other countries grappling with the same issues.

We have contributed to the literature on ELV in three significant ways. First, we have outlined through Study 1 the estimated number of ELVs that will be generated and will be required to be siphoned off for each category of vehicles, viz passenger vehicles, commercial vehicles, three-wheelers, and two-wheelers. Secondly, basis the survey reports, we assessed people's perception vis-à-vis decommissioning of ELV and reported the ground realities essential for policy formulation. Third, we contribute to the literature on cleaner and sustainable industries by outlining how decommissioning old vehicles could result in societal and industrial benefits. Studies that can globally assess people's perception of ELV and the benefits the stakeholders derive from it can employ the survey instrument designed for this study. We have also outlined how these specific measures can result in a sustainable circular economy.

The structure of our study is as follows: Section 2 provides an overview of the current policy and ELV management, a secondary data analysis (Study 1) using annual reports from the Society of Indian Automobile Manufacturers (SIAM), and primary data collection through surveys. The primary data analysis is divided into two parts: Study 2A involves qualitative analysis of open-ended survey items using coding and thematic analysis techniques. In contrast, Study 2B entails quantitative analysis of closed-ended survey items using appropriate statistical methods. The results and analysis from Study 1 and Study 2A and 2B are presented in Section 3, followed by a discussion of the findings, implications, and limitations. The study concludes with policy recommendations based on the comprehensive analysis conducted.

2. Review of Literature and Hypotheses Development

A nation's ELV process can be initiated via two routes: legislation on ELV and existing environmental protection laws. While European Union (EU), Japan, South Korea, and China use formally drafted legislation on ELV, the USA, Canada, and Sweden use the existing laws to organize the ELV process (Kazmierczak et al., 2004; (Saidani *et al.*, 2019; Sakai *et al.*, 2014). In this regard various industrialized economies are moving towards greener technologies and improved R&D innovation to reduce negative environmental impact (Song *et al.*, 2023). Considering the number of vehicles, China will play a significant role in ELV management (Li *et al.*, 2014). Further, studies suggest that total factor productivity of industrial provinces in China also improved only with considering environmental factors (Song and Li, 2020).There are similarities in the processes and working of ELV management in these countries, but they differ in effectiveness and efficiency (Sakai *et al.*, 2014). The recycling rate also varies among nations; for example, in Italy, it remains around 80% (Santini *et al.*, 2011). The literature also accounts for the ELV processes as laid out succinctly for various stakeholders across the globe (Corporation, 2017). There have been obstacles to ELV legislation in India, the prominent being the handling and subsequent disposal of hazardous waste (Giannouli *et al.*, 2007). However, studies have delved into these factors to provide a critical and insightful interpretation that can contribute to the development of an effective legislative policy and framework (Molla *et al.*, 2022). The ELV management proposed in the report outlines the difficulties and precautions in managing the whole process. While the USA and EU reveal the annual ELVs and the recovered ELVs, India still lacks a mechanism to ascertain ELVs (Bauner, 2011; Saidani *et al.*, 2019), let alone recover the same. The annual scrapping rate of 7% and roughly 84 million ELVs worldwide (Yang *et al.*, 2019) suggests that the Indian response is delayed and, if not implemented positively, will further harm the country's environment, health, and economy. The Voluntary Vehicle Fleet Modernization Programme (MoRth, 2016) proposed scraping 28 million vehicles purchased on or before March 31, 2005, and replacing them with BS-IV-compliant vehicles. The vehicles used for more than ten years were proposed to be scrapped, assuring a 25-30% reduction in air pollution ((MoRth, 2016).

In March 2018, the Government of India (GoI) extended the effective end of an automobile's life to 20 years, and the implementation was set for April 2020. Initial drafts hinted at the possibility of setting up centers for scrapping, which had been placed out in October 2019. Seventy-five scrapping stations are proposed to be set up in phase one under the new scrapping policy 2021. Private motor players like Tata Motors, Mahindra and Mahindra, among others, signed MOUs in December 2021 with the government to establish scrapping centers (IBEF, 2022). However, with the introduction of the new scrappage policy (Figure 1), its exposure was ultimately in diverse arrangements compared to the earlier versions showing the ELV management dynamics (MoRTH, 2019).

[Insert figure 1 here]

Study Rationale

The rising levels of pollution in prominent Indian cities signal an alarming situation. For instance, the average air quality index (AQI) level touches 300 for most of India's cities. According to the world regional capital ranking arranged based on average annual PM 2.5 concentration ($\mu g/m^3$), Delhi has been ranked one (IQAir Visual, 2019). GoI accepts that air pollution is emerging as a critical problem for India. Vehicular pollution is one of India's most prominent air pollution causes (Maji *et al.*, 2016). The transition of BS-IV to BS-VI came into effect on April 1, 2020, a scheme involving the scrapping of old vehicles leading to higher sales of BS-VI vehicles, which can reduce emissions drastically. The GoI skipped BS-V, which had to be implemented by 2020, with an earnest motive of combating emissions (Bharj *et al.*, 2019; Hora *et al.*, 2018). BS-VI norms promise to tighten the particulate matter (PM) mass emission limits and introduce the particulate number limits for light and heavy-duty vehicles (ICCT, 2016).

However, the practical implementation of the plan is a tricky proposition, partly due to a lack of general awareness about ELV management and the lack of know-how as a status quo for introducing the rigorous and challenging process of ELV management. Regarding the new guidelines by GoI regarding the implementation of Cleaner Fuel and new BS-VI regulations in 2020, various challenges are being faced by big Indian auto OEMs (original equipment manufacturers) such as Tata and Mahindra. To meet the expectations of the GoI, the OEMs have to further indulge in enormous expenditures, which will not be rewarding in the initial years of its establishment. However, the new compliance would also benefit Indian auto manufacturers when they can discover export markets to amortize development expenses over a high production volume. Therefore, the GoI's vision currently remains inadequate for the circular/sustainable economy of ELV in India. They must consult successful regulatory ELV frameworks in the EU and USA so that the OEMs are associated with building the circular economy around ELV management.

The millennials in India constitute a large proportion of the population; they have the proper knowledge to choose better options. The major problem for the general population is the reluctance to change. The enforcement part might come from the Government, but people might find new ways of avoiding it. The ELV management policy and directives are in the initial stages in India, which require stakeholders' support. Formulation of legislation at the highest level, education of the masses regarding the policy, approval of OEMs, and the Government's support will remain crucial to implementing the ELV framework practically (Lathia and Dadhaniya, 2019). This study has been undertaken to study the gap between the regulatory framework, viz., regulations on ELV management, and stakeholders' (read general public) perception of ELV management. The stakeholders' awareness of the ELV management regulation will help implement the regulation. The policy made by the GoI on ELV management, scrappage, BS-VI norms, and the automobile industry plans has been considered and included in this study. Therefore, we formulate the following hypothesis:

H1: There is a positive perception of the general public in India regarding proposed ELV management regulations.

H2: There is a positive perception of the general public in India concerning decommissioning their old vehicle.

ELV Management in India

Scrapping in India (Figure 2) is rather time-consuming work. The first step for anyone willing to let go of one's old vehicle is to find a government-authorized scrapper. In the same context, the authorities would ascertain that the person owns the vehicle and a third party does not present an impounded or abandoned vehicle. In India, people prefer keeping the old vehicle instead of scrapping them, hence the risk of impounding augments. Secondly, the person should have all the valid documents regarding ownership and the latest regulatory compliances of the ELV. Suppose one fails to have it; in that case, the owner's identity is matched digitally with the VAHAN database. The person will receive a receipt for properly validating the vehicle's transfer to the scrapper. Thirdly, the person opting for legal decommissioning should carry mandatory documents such as the vehicle's Registration Certificate (RC) and pollution check/fitness certificate.

Legal purchase documents and hire-purchase agreement documents are required on a case-to-case basis. Additionally, the death certificate is required from the owner if there is a case of inheritance due to the original owner's death. Fourthly, the authorized scrapper shall accept self-certified copies from the owner, like a PAN card, a cheque from the owner's bank account (crossed), and any other identity proof other than the requested documents. The scrapper will then issue a Certificate of Deposit as evidence to transfer the vehicle's ownership altogether. Lastly, the authorized representative shall digitally pay the account payee cheque with an obligation to receive a due receipt from the owner. Then, the authorized representative will be responsible for the vehicle's safe custody for six months from the 'Certificate of Vehicle Scrapping' issue.

[Insert figure 2 here]

3. Results

3.1 Study 1: ELV Growth Projections

Methodology for Annual and Cumulative Demand for New ELVs: We ascertained a macro perspective on the whole issue of ELV management in India by employing secondary data analysis to fulfill two primary objectives. First, to provide an estimate of the projected annual demand for the new ELVs over the period of 15 years from 2020 – 2035. and second, to assess the growth rate in new annual ELVs over the same time horizon. Fulfilling these two objectives will provide quantitative figures for the macro-level demand for new ELVs and their expected growth rate. It will validate the whole discussion and reinforce the urgency and relevance of prompt action.

Since the standard life of a vehicle (from sale) before reaching the ELV stage is taken as 15 years, the estimation of annual demand for new ELVs can be conveniently obtained by projecting the domestic vehicle sales in any particular year to a period of 15 years hence. For example, the estimated demand for new ELVs for any vehicle category (say, passenger vehicles) in 2034–35 will be approximately equal to the domestic sales of passenger vehicles in 2019–20. Since the annual Indian domestic sales data of all vehicle categories have been taken from 2005-06 till 2019-20, the estimated new Annual ELVs demand for all vehicles category has been obtained from 2020-21 to 2034-35.

3.1.1 Sample and Period

We obtained the secondary data for analysis from the annual reports available on the official website of the Society of Indian Automobile Manufacturers (SIAM). Variables of concern for this analysis are the domestic yearly sales figures for different vehicle categories (Passenger, Commercial, Three Wheelers, Two Wheelers) and their sub-categories. The standard time frame of 15 years from the vehicle sale has been taken as the benchmark period before it reaches the ELV stage. Since forecasts from 2020-21 would be relevant in the contemporary context, we have taken the annual data from SIAM from 2005-06 till 2019-20 (the latest available).

3.1.2 Results for Annual and Cumulative Demand for New ELVs

The obtained figures are provided in table 1. All vehicle categories will rise from 8.906 million (2020-21) to 21.5 million (2034-35).

[Insert table 1 here]

Another interesting dimension of this analysis would be to present the cumulative number of new ELVs demanded in any given year. This presentation will approximately indicate the total size of the ELV market for different vehicle categories till that particular year. The numbers can be conveniently obtained by adding up the annual new ELV demands up to that year (table 2). The total cumulative ELV market size is expected to touch approximately 39.8 million in 2034-35 for passenger vehicles, about 108 million in 2034-35 for commercial vehicles, more than 8.7 million in 2034-35 for three-wheeler vehicles, and more than 225 million in 2034-35 for two-wheeler vehicles. The cumulative market size for ELVs across all vehicle categories is expected to exceed 285 million in 2034-35.

[Insert table 2 here]

3.1.3 Estimation and Results for Growth Rates of New ELVs: Log-Lin Regression & CAGR: After getting the estimate for the annual demand for new ELVs, the next step would be to compute the growth rates for these projections, which would give a rough estimate of the ELV industry's growth and how its demand would evolve over the next one and a half decades. The analysis provides growth rates for the projected demand for all major segments of the auto industry, thus providing a basis for detailed policy formulation and planning by corporate entities for each segment.

We have employed two popular methods to compute the desired growth rates. First, we used Log-Linear regression, in which we regressed the log of the dependent variable on time. The beta coefficient this obtained provides the growth rate as it represents the relative change in the dependent variable over time or the rate of change in the dependent variable for each time unit.

We formulate the following regression equations to estimate the Log-Lin Regression:

- Log (Passenger Vehicles) = $\alpha + \beta$*Time … (1)
- Log (Commercial Vehicles) = $\alpha + \beta$*Time … (2)
- Log (Three Wheelers) = $\alpha + \beta$*Time … (3)
- Log (Two Wheelers) = $\alpha + \beta$*Time … (4)
- Log (All Vehicles) = $\alpha + \beta$*Time … (5)

These are ordinary least square regressions that can be estimated using any standard econometric/statistical software package. We have used the EViews version 8 software for this study. Another widely used method is to compute the Compounded Annual Growth Rate, also popularly known as the CAGR. It gives the annualized average growth rate for the entire period in the study. It differs from other growth rate measures in that it provides the smoothened/uniform annualized growth rate or the same growth rate required each year to reach the end value starting from the beginning.

Compounded Annual Growth Rate (CAGR) = $[V_{End}/V_{Start}]^{1/T} - 1$ …(6)

Where: V_{End} = Value of the Variable at the end of the time period;

V_{Start} = Value of the Variable at the Start of the time period; and

T = Time Period (in Years).

The results from the estimation of the Log-Lin regression model and CAGR are provided (table 3). All five estimated regression models are highly significant (with high *F-Statistic* values and probability of *F-Statistic* < 0.000) and have good explanatory power (high *R-Square*). The β coefficient associated with the independent variable (time) provides the growth rate change in the estimated annual demand for new ELVs yearly. All the coefficients are statistically significant ($p < 0.000$). The growth rates for annual ELV estimates are highest for two-wheeler vehicles (8.31%), followed by passenger vehicles (6.83%), commercial vehicles (5.42%), and three-wheeler vehicles (4.34%). The overall growth rate for all combined categories is 7.86%, owing to the higher weightage of two-wheeler vehicles. CAGR for the vehicle categories are also in the same order and not very different numerically: Two-wheeler vehicles (6.21%), passenger vehicles (6.09%), commercial vehicles (4.88%), and three-wheeler vehicles (3.88%). The overall CAGR for all vehicle categories is 6.07%. The lower CAGR reflects its property of smoothening out the wide variations in growth rate caused by significant increases or decreases.

[Insert table 3 here]

3.2 Study 2

3.2.1 Method

Drawing from Study 1, our objective was to investigate the perceptions of vehicle owners regarding the issues surrounding End-of-Life Vehicles (ELVs) and their effective management. This study revealed a significant increase in ELV numbers in India, indicating an urgent need for attention. To gather primary data, we administered a comprehensive test battery in two major metropolitan cities, Delhi and Mumbai. These cities represent a microcosm of new India, attracting individuals from nationwide seeking opportunities and livelihoods. By sampling perceptions from these cities, we aimed to capture a broad spectrum of sentiments from across India. The survey was strategically conducted in various parts of the cities, allowing for comprehensive observations and conclusions regarding government processes and policies related to ELV decommissioning and management. The pilot test was administered to 100 people, 50 owning commercial and 50 private vehicles (Kite and Whitley, 2018; Page and Meyer, 2000).

3.2.2 Measures:

The decommissioning of End-of-Life Vehicles (ELVs) presents both advantages and disadvantages. We designed a test battery utilizing a five-point Likert scale to measure vehicle users' perception of decommissioning. The development of this test battery involved multiple consultations with subject matter experts from academia and industry. These consultations were conducted iteratively to ensure the face and content validity of the test battery, enhancing its reliability and scientific rigor (DeVellis, 2017). By employing this rigorous approach, we aimed to accurately capture and assess the perceptions of vehicle users regarding ELV decommissioning

3.2.3 Participants

According to the Economic Survey (2018-19), Delhi and Mumbai account for 3.35 and 1.2 million light vehicles, respectively. This research encompassed approximately 5 million individuals residing in the combined areas of Delhi and Mumbai. Our sampling frame included vehicle owners and hired operators responsible for operating and plying commercial vehicles along selected routes to ensure comprehensive coverage. Employing a random sampling method, we obtained responses from participants, thereby minimizing the potential for selection bias (Hair, 2014). This sampling approach significantly enhances the generalizability and reliability of the study's findings, thereby bolstering its scientific rigor. By strategically selecting various parts of Delhi and Mumbai, we ensured comprehensive coverage and representation within the sample. The determination of the adequate sample size was guided by the population size of 5 million, a margin of error of 4%, and a confidence level of 99%. Accordingly, the required sample size of 1038 was carefully selected using a transparent and systematic sampling procedure. This rigorous approach mitigated the potential for sampling bias and ensured a representative sample from the target population, further strengthening the scientific validity of the study. (Hair, 2014). For the survey, approximately 800 Questionnaires in Delhi NCR (including Kalkaji, Govindpuri, Laxmi Nagar, GTB Nagar, Pitampura, Rohini, Gurgaon, and Noida) were administered, and 300 questionnaires in Mumbai (including Juhu, Goregaon, Andheri, and Navi Mumbai) were administered.

Out of the 1100 questionnaires administered, we could collect back 920 survey responses, and 22 respondents had missing data issues. Those who did not answer more than 10% of the instrument were eliminated (Little and Rubin, 2019). Another ten respondents were excluded from the data as their responses had high variation. The standard deviation of each candidate's responses formed the basis of such elimination. Also, variability of less than 0.30 showed ten respondents' lack of engagement. This analysis negated missing data and non-response bias from the dataset (DeVellis, 2017). We employed specific notes cautioning respondents that there are no right or wrong answers in the survey, and this exercise ensured that there was minimum social desirability bias to answer the questions in a particular manner (Paulhus and Vazire, 2007).

3.2.4 Study 2A: Perceptual Analysis

The demographic and related questions asked to the respondents in Table 4 follow. We provide the statistics based on each question asked:

[Insert table 4 here]

The respondents were asked the following open-ended questions:

1. *What is your perception of the decommissioning of old vehicles?*

In rapidly developing nations like India and China, the number of automobiles purchased increased exponentially (Sakai *et al.*, 2014). According to MoRTH (2018), the number of vehicles registered in India in the last 25 years is more than 200 million. In this regard, commercial and private vehicle owners from India's most prominent metropolitan markets – Delhi and Mumbai, were interviewed to know their perception of de-registering old vehicles over 15 years old. We received mixed responses and analyzed the same through the NVIVO 12 software. Following is an excerpt from the interviews taken that support the analysis:

> *Decommissioning according to me is the need of the hour presently. Especially when staying in a metropolitan like Delhi, which is already very polluted. The vehicles that run on Delhi roads are sometimes very old like 10 to 15 years old and mostly use diesel therefore releasing very harmful emissions. So I hold a very positive perception towards decommissioning and firmly support it.*

I think this attempt can help the government achieve positive result. This surely would reduce pollution but can't say whether it will be sustained. As it will be followed by immediate purchase of new cars.

The responses ranged from complete unfamiliarity with decommissioning old vehicles to neutral perception. Some opined that it would boost industrialization, increase the country's welfare, and should be made compulsory (figure 3). The word count and the weighted percentage have been tabled (table 5). The treemap shows a mixed picture of the general perception of the public (figure 4).

[Insert table 5 here]

[Insert figure 3 here]

[Insert figure 4 here]

2. *Are you aware of the benefits of decommissioning old vehicles? If yes, please list some of the benefits.*

There were mixed responses from the respondents concerning the benefits of decommissioning ELVs. The respondents opined that decommissioning ELVs would reduce vehicular pollution, a notion that is in sync with the GoI reports (MoRTH, 2016). But the respondents also opined that this policy would not benefit the vehicle owners personally; however, it may help the GoI reduce environmental hazards. Other responses ranged from the curb in traffic snarls to more parking spaces. The study here presents an excerpt from the interviews conducted:

Of course, we will get rid of pollution to some extent. It will help our future generations to live in a less polluted environment. Parking spaces will be easily available. Time will be saved due to less congestion on the roads.

Yes, it will reduce air pollution and traffic on the roads. Further, it will help in creating awareness among people about ill effects of using old vehicles.

It would reduce running of old vehicles on roads and reduce pollution greatly. Economic point of view can be with decommissioning coming into play, sale of new cars will boost contributing to the growth of the automobile industry.

3. *Suggest some measures you feel the Government can take to improve its decommissioning policy.*

The respondents were first asked if they knew about the current policies pursued by the GoI concerning decommissioning old vehicles. The vehicle owners' responses ranged from requesting the GoI to increase the tenure (effective age) for old vehicles for decommissioning to effectively advertising the ELV management policies. The following excerpt considers the interviewee's viewpoint and suggestions:

> *The government should increase the tenure of the vehicles especially for those who repair their vehicles repair their vehicles regularly. Government should also provide extra benefits while surrendering old vehicles like free insurance on purchase of new vehicles.*
>
> *Such efforts by the government are not known to maximum people. Therefore, government should create awareness and advertise about such new initiatives.*
>
> *The government should encourage people by giving better interest rates on car loans for those who give up their old vehicles and provide some compensation for maintenance of owned vehicles. The government should improve public transport system so that people prefer public system to their own vehicles.*

The general public opines that the GoI should initiate several measures, ranging from a sound scrappage management system, adequate financial incentives to vehicle owners, and awareness programs. Further, GOI also supports ELV management companies, introduced strict penal provisions for defaulters, and technology up-gradation drives have also been started. The survey highlighted that 69.3% of vehicle users think decommissioning ELVs would benefit society, and 15.5% think it will not. The rest of the users, i.e., 15.2%, were unsure.

3.2.5 Study 2B: Main Analysis

Factor Analysis has been used to segregate the different benefits of decommissioning the ELVs and then club them into relevant factors (table 6). Factor analysis is considered a reasonably robust test even in cases of departures from normality when the sample size is relatively large; in this case, we had a large sample size (Hair, 2014). The Variance Inflation Factor (VIF) values for each item in the factor analysis model ranged from 1.365 to 2.489, indicating the absence of multicollinearity issues. To validate the factor analysis model, we conducted Bartlett's test of sphericity, which evaluates the overall significance of correlations within the correlation matrix. The chi-square value for this test was calculated as 3671.37, with 45 degrees of freedom. The resulting p-value indicated a significant relationship among the variables. Additionally, the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy was computed to assess the strength of relationships among the scale items. The obtained KMO value of 0.926 surpassed the commonly recommended threshold of 0.6, indicating high inter-item correlations and justifying the continuation of the factor analysis. Furthermore, the total variance extracted summary revealed that the eigenvalues of the first two extracted factors accounted for a cumulative variance of 60.819%, satisfying the Kaiser criterion for factor retention. (Hair, 2014).

We employed the Maximum Likelihood extraction method for conducting factor analysis. The Promax rotation method with Kaiser Normalization was utilized to enhance the interpretability of the factors. Through iterative processes, it was determined that a two-factor solution yielded the most appropriate structure, capturing the underlying dimensions of the data. The pattern matrix revealed the factor loadings of the items, with two items being excluded from the final matrix due to low loadings and cross-loadings. These exclusions were based on careful consideration of face validity and the content of the indicators. The resulting factors were labeled as "societal benefits" and "industrial benefits," aligning with the underlying themes inferred from the data. The factors demonstrated excellent reliability, as evidenced by the reliability scores presented in Table 6. Moreover, they exhibited satisfactory construct validity (convergent validity in this context), with the average variance extracted exceeding 0.50 for both factors, as indicated in Table 6. These findings not only enhance the robustness and scientific rigor of the study but also validate the measurement properties of the factors derived from the factor analysis.

[Insert table 6 here]

The constructs offer a measure of the general public’s perception regarding decommissioning old vehicles and the vehicles’ ELV management. We conducted a one-sample t-test on the summated scores with the test value=3, α=0.01. The statistical report depicts the public perception of ELV management’s social benefits (Mean =3.67, SD=0.82) as positive and significant (*t=24.25*, *p<0.001*). Therefore, we accept *H1*. Similarly, the general public sentiment about ELV management’s industrial benefits (Mean=3.53, SD=0.88) is mainly positive and significant (*t=17.79; p<0.001*); therefore, we accept *H2*.

[Insert table 7 here]

In order to comprehensively investigate people's perception of decommissioning End-of-Life Vehicles (ELVs) in India, we employed a rigorous mixed-methods approach. The qualitative component provided valuable insights into the prevailing sentiments and attitudes towards ELV decommissioning and the associated management process. Through qualitative data analysis, a prevailing awareness of the detrimental environmental effects of vehicles and their impact on general well-being, including reduced vehicular pollution and improved road spaces, emerged. To substantiate and enhance the validity of these qualitative findings, we performed Factor Analysis, followed by a one-sample t-test (see Table 7). These quantitative analyses yielded robust empirical evidence that supports the positive perception of the ELV management process envisioned in India.

4. Discussion, Implications, and Recommendations

In Study 1, we estimated the annual End-of-Life Vehicle (ELV) figures and made cumulative projections of ELVs for a 15-year period. This exercise was done to ascertain the future market size of ELVs, highlighting the critically associated with effective ELV management. Study 1, therefore, accentuates the magnitude of challenges posed by the high ELV demands in the future and calls for proactive management of ELVs. The systematic estimation methodology employed in this study ensures scientific rigor and enhances our understanding of the implications and urgency associated with comprehensive ELV management strategies. Currently, the scrappage management sector suffers from inadequate infrastructure and a lack of regulation, highlighting the need for government intervention. Notably, India's proposed ELV management policy presents a significant business opportunity, with an estimated annual market value of $6 billion. (INR 43,000 crore) (Thakkar and Shyam, 2020). BS-VI emission norms have been adopted by the GoI, surpassing the BS-V norms, showcasing that they are serious about the emission standards. The System Dynamics (SD) methodology, followed by other countries like Italy and China, can be replicated in the Indian ELV management system (Li *et al.*, 2016). The ELV management system managers can consider the various economic and other country-specific factors to bring an efficient SD methodology to India (Rosa and Terzi, 2018).

This study provides a comprehensive understanding of people's awareness and perceptions regarding End-of-Life Vehicle (ELV) management in India, considering the country's size and diverse urban landscapes facing ELV-related challenges. Primary data collection (Study 2) was conducted in Delhi and Mumbai, two prominent metropolitan cities in India. While the study primarily focused on the implications for the Indian government, the issues discussed, and perceptions highlighted have broader relevance, particularly for countries lacking an ELV management policy or in the early stages of developing such strategies.

The analysis of the study revealed several key findings. Participants strongly believed that decommissioning ELVs would yield societal and industrial benefits, notably by reducing pollution levels and addressing parking challenges, leading to a substantial supply of reusable scrap materials. Respondents emphasized the importance of the government institutionalizing a comprehensive scrap management policy and developing the necessary infrastructure to handle ELV-generated waste. By shedding light on people's perceptions and advocating for improved ELV management practices, this study provides not only valuable insights for the Indian government but also offers valuable lessons for countries without established ELV management policies and those in the early stages of policy development. The study highlights the potential societal, environmental, and economic benefits of effective ELV management, ultimately contributing to sustainable and responsible waste management practices in the automotive sector.

4.1 Recommendations to the Government

India imports around 5-6 million tons of ferrous shredded scrap per annum due to a shortage of quality steel scrap generated in the country—the import of crude amounts to a massive sum of Rs 8000 billion annually. Implementing the policy on ELV and scrappage management will foster a sustainable circular economy: better efficiency of new vehicles will reduce the fuel cost (and valuable foreign exchange reserves), steel would be locally produced, designated shredding centers will be finalized, air pollution would remain in check, consumers and OEMs would comply with rules, thereby fostering a circular economy (van den Bergh, 2020; Lahane *et al.*, 2021; Saidani *et al.*, 2019). The GoI can also develop a waste management database that will keep track of the metals and waste produced in the decommissioning process and make someone nationally and internationally responsible for managing the waste pile (van den Bergh, 2020; Cossu and Lai, 2015). It will record every material's contribution and how its use can be optimized (Giannouli *et al.*, 2007).

The vehicle scrappage policy proposed by the GoI should have mandatory replacement programs instead of the prevailing voluntary option of surrendering ELVs. Voluntary options have proven ineffective in convincing people—the guidelines for replacing a car with another must be appropriately accommodated. The policymaker needs to properly assess the usage of the replaced vehicles and the vehicles presently in working conditions on the roads. Lessons from European countries and China's unsuccessful attempts at Heavy Duty Vehicles (HDVs) can be learned where Nitrogen Oxide (NOx) emission norms were not met at low speeds (Lowell and Kamakaté, 2012). Additionally, the authorities should be cautious in giving out-of-proportion subsidies, as seen in the USA's 'Cash for Clunkers' (Chakravarty, 2020). It should be managed to confer to the region, vehicle categories, or even budget that must be sporadically reviewed to get optimum results. The policy should fixate on when vehicle replacement becomes due and the subsequent subsidy the vehicle owner will get on decommissioning the vehicle. The GoI should lower subsidies for ELVs and provide much higher subsidies to the new vehicle holders (Jia *et al.*, 2018). The Government must also finance the replacement scheme with a lesser interest rate.

4.2 Recommendations for Industry

The scrapping of old vehicles generates demand for new ones. Delhi alone accounts for 45% of diesel vehicles. Moreover, a significant segment that will boost demand is commercial vehicles, as they are diesel-run. Under the new incentivized policy, a 50% excise duty discount was offered, meaning that cars' cost/price will decrease, increasing the demand due to economical rates. On the other hand, the import price of ferrous scrap is $289 per ton and 12.5% Countervailing Duty (CVD), equivalent to Rs. 20,522 per ton. The domestic influx of ferrous scrap from the decommissioned vehicles could easily substitute this import. The scrap from the ELVs can be used by the building or construction industry also that can use non-ferrous metals, plastics, and glass, among numerous other materials, to help construct roof tiles, aluminum sheets, and plastic pipes while confirming the safety measures (Wong *et al.*, 2018). Hence this policy will help the new domestic corporations meet break-even sooner, and the old ones cut additional costs and have increased demand leading to sustainability and contributing to the circular economy.

4.3 Recommendation for Policy Formulation

The GoI should promote the usage of electric and hybrid vehicles. All existing vehicles under government control, which are older than 15 years, should be replaced with electric vehicles in a phased manner. Like European countries, the GoI should employ a strict carrot-and-stick policy by levying a huge surcharge or fee on inefficient and old vehicles. There should be a strategic decommissioning of ELVs that contribute heavily to air pollution. There should be more excise duty incentives, road tax for the replacement vehicle, and auto manufacturers' discounts. Policy recommendations should benefit the vehicle owners accepting the Government's ELV framework**.**

It is estimated that a well-prepared ELV management can create great opportunities. Auto recycling in India is currently unorganized; if around 25% of the total number of cars are recycled, it can provide USD 2.9 billion (Agarwal, 2017). It is also estimated that 21.8 million vehicles in India will reach the end of life by 2025 and contribute 10 million tonnes of steel scrap (TERI, 2019). If we concentrate on this in the future, it could act as an acute agent to revitalize the automobile sector, which currently is reeling under subdued sales.

4.4 Limitations and Future Studies

The study on ELV management has highlighted the issues concerning India, which is a populous country with a significant proportion of ELVs, and the rate at which the ELVs will grow is also something that the administrators need to proact. However, we have been able to administer the test battery concerning the people's perception in only two metropolitan cities of the country. India has significant Tier 2 and Tier 3 cities and towns, not to mention numerous villages also facing the issues of ELVs. Therefore, complete generalization for policy formulation is far-fetched at this time. Future studies could better represent rural semi-rural areas, suburbs, towns, and other cities to fully understand people's perceptions of ELV management.

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TABLE 1: PROJECTED NEW ANNUAL ELV DEMAND

PART A: ESTIMATES FOR THE YEARS 2020 – 2028

(NO. OF UNITS)

Category	**2020-21**	**2021-22**	**2022-23**	**2023-24**	**2024-25**	**2025-26**	**2026-27**	**2027-28**
Passenger Cars	882208	1076582	1203733	1220475	1528337	1972845	2031306	1874055
Utility Vehicles	194502	220306	245284	225621	272740	315123	363772	553662
MPVs/Vans	66366	83091	100865	106607	150256	213574	234761	237298
Total Passenger Vehicles	**1143076**	**1379979**	**1549882**	**1552703**	**1951333**	**2501542**	**2629839**	**2665015**
Medium & Heavy CVs	207472	275556	274582	183495	244944	323059	349216	268689
Light CVs	143569	192209	215912	200699	287777	361846	460283	524522
Total Commercial Vehicles (CVs)	**351041**	**467765**	**490494**	**384194**	**532721**	**684905**	**809499**	**793211**
Three Wheelers	**359920**	**403910**	**364781**	**349727**	**440392**	**526024**	**513281**	**538290**
Scooters	909051	940617	1050109	1148007	1462534	2057604	2558981	2923424
Motorcycles	5810599	6547195	5768342	5831953	7341122	9013888	10073303	10085000
Mopeds	332741	354760	413759	431214	564584	697418	776866	788761
Total Two Wheelers	**7052391**	**7842572**	**7232210**	**7411174**	**9368240**	**11768910**	**13409150**	**13797185**
Grand Total	**8906428**	**10094226**	**9637367**	**9697798**	**12292686**	**15481381**	**17361769**	**17793701**

PART B: ESTIMATES FOR THE YEARS 2028 – 2035

(NO. OF UNITS)

Category	**2028-29**	**2029-30**	**2030-31**	**2031-32**	**2032-33**	**2033-34**	**2034-35**
Passenger Cars	1786826	1877706	2025097	2103847	2174024	2218489	1695441
Utility Vehicles	525839	552135	586576	761998	922322	941474	946010
MPVs/Vans	190844	171395	177535	181737	192235	217426	132124
Total Passenger Vehicles	**2503509**	**2601236**	**2789208**	**3047582**	**3288581**	**3377389**	**2773575**
Medium & Heavy CVs	200618	232755	302397	302567	340781	390732	224806
Light CVs	432233	382193	383307	411515	516135	616579	492882
Total Commercial Vehicles (CVs)	**632851**	**614948**	**685704**	**714082**	**856916**	**1007311**	**717688**
Three Wheelers	**480085**	**532626**	**538208**	**511879**	**635698**	**701005**	**636569**
Scooters	3602745	4500920	5031678	5604673	6719909	6701430	5566036
Motorcycles	10481115	10726013	10700406	11094547	12620690	13598190	11214640
Mopeds	722920	748628	723767	890518	859518	880227	636940
Total Two Wheelers	**14806778**	**15975561**	**16455851**	**17589738**	**20200117**	**21179847**	**17417616**
Grand Total	**18423223**	**19724371**	**20468971**	**21863281**	**24981312**	**26266179**	**21546390**

TABLE 2: PROJECTED NEW CUMULATIVE ELV DEMAND
PART A: ESTIMATES FOR THE YEARS 2020 – 2028

(NO. OF UNITS)

Category	**2020-21**	**2021-22**	**2022-23**	**2023-24**	**2024-25**	**2025-26**	**2026-27**	**2027-28**
Passenger Cars	4016847	5093429	6297162	7517637	9045974	11018819	13050125	14924180
Utility Vehicles	789748	1010054	1255338	1480959	1753699	2068822	2432594	2986256
MPVs/Vans	304816	387907	488772	595379	745635	959209	1193970	1431268
Total Passenger Vehicles	**5179618**	**6559597**	**8109479**	**9662182**	**11613515**	**14115057**	**16744896**	**19409911**
Medium & Heavy CVs	855043	1130599	1405181	1588676	1833620	2156679	2505895	2774584
Light CVs	548480	740689	956601	1157300	1445077	1806923	2267206	2791728
Total Commercial Vehicles (CVs)	**1403523**	**1871288**	**2361782**	**2745976**	**3278697**	**3963602**	**4773101**	**5566312**
Three Wheelers	**1565564**	**1969474**	**2334255**	**2683982**	**3124374**	**3650398**	**4163679**	**4701969**
Scooters	5327914	6268531	7318640	8466647	9929181	11986785	14545766	17469190
Motorcycles	23595177	30142372	35910714	41742667	49083789	58097677	68170980	78255980
Mopeds	2353543	2708303	3122062	3553276	4117860	4815278	5592144	6380905
Total Two Wheelers	**31276634**	**39119206**	**46351416**	**53762590**	**63130830**	**74899740**	**88308890**	**102106075**
Grand Total	**39425339**	**49519565**	**59156932**	**68854730**	**81147416**	**96628797**	**113990566**	**131784267**

PART B: ESTIMATES FOR THE YEARS 2028 – 2035

(NO. OF UNITS)

Category	**2028-29**	**2029-30**	**2030-31**	**2031-32**	**2032-33**	**2033-34**	**2034-35**
Passenger Cars	16711006	18588712	20613809	22717656	24891680	27110169	28805610
Utility Vehicles	3512095	4064230	4650806	5412804	6335126	7276600	8222610
MPVs/Vans	1622112	1793507	1971042	2152779	2345014	2562440	2694564
Total Passenger Vehicles	**21913420**	**24514656**	**27303864**	**30351446**	**33640027**	**37017416**	**39790991**
Medium & Heavy CVs	2975202	3207957	3510354	3812921	4153702	4544434	4769240
Light CVs	3223961	3606154	3989461	4400976	4917111	5533690	6026572
Total Commercial Vehicles (CVs	**6199163**	**6814111**	**7499815**	**8213897**	**9070813**	**10078124**	**10795812**
Three Wheelers	**5182054**	**5714680**	**6252888**	**6764767**	**7400465**	**8101470**	**8738039**
Scooters	21071935	25572855	30604533	36209206	42929115	49630545	55196581
Motorcycles	88737095	99463108	110163514	121258061	133878751	147476941	158691581
Mopeds	7103825	7852453	8576220	9466738	10326256	11206483	11843423
Total Two Wheelers	**116912853**	**132888414**	**149344265**	**166934003**	**187134120**	**208313967**	**225731583**
Grand Total	**150207490**	**169931861**	**190400832**	**212264113**	**237245425**	**263511604**	**285057994**

Table 3: Log-Lin Regression Result & Growth Rates

Dependent Variables	**Overall Model Results**			**Coefficients Summary**			**CAGR**
	R-Square	**F-Stat.**	**Prob.**	**Beta**	**Prob.**	**Growth Rate**	
Log (Passenger_Vehicles)	0.8272	62.25	0.000	0.0683	0.000	6.83%	6.09%

Log (Commercial_Vehicles)	0.6614	25.39	0.000	0.0542	0.000	5.42%	4.88%
Log (Three_Wheelers)	0.8211	59.67	0.000	0.0434	0.000	4.34%	3.88%
Log (Two_Wheelers)	0.9140	138.17	0.000	0.0831	0.000	8.31%	6.21%
Log (All_Vehicles)	0.9076	127.71	0.000	0.0786	0.000	7.86%	6.07%

Table 4: Descriptive Analysis

Vehicle Type		Frequency	Percent
Valid	Private Vehicle	543	61.8
	Commercial Vehicle	335	38.2
	Total	878	100.0
Fuel Used		Frequency	Percent
Valid	Petrol	438	49.9
	Diesel	188	21.4
	CNG	249	28.4
	Others	3	0.3
	Total	878	100.0
Do you know about any government policy regarding- Decommissioning/ scrapping of 10-year-old (diesel) and 15 years old (petrol) vehicles?		Frequency	Percent
Valid	Yes	542	61.7
	No	336	38.3
	Total	878	100.0
Do you know about any government policy regarding- Incentive policy for decommissioning old vehicles?		Frequency	Percent
Valid	Yes	285	32.5
	No	593	67.5
	Total	878	100.0
What incentives (monetary) from the Government would convince you to give up your old vehicle? (in INR)		Frequency	Percent
Valid	10000-20000	58	6.6

	20000-30000	80	9.1
	30000-40000	77	8.8
	40000-50000	104	11.8
	Above 50000	559	63.7
	Total	878	100.0

Table 5: Word count and weighted percentage of Respondent's perception

Word	Length	Count	Weighted rate (%)
Good	4	153	2.57
Pollution	9	151	2.53
Policy	6	125	2.10
Government	14	124	2.08
reduce/reduces	13	109	1.83
Yes	3	105	1.76
Idea	4	92	1.54
Old	3	86	1.44
Vehicle	7	86	1.44
Vehicles	8	79	1.33
decommissioning	15	76	1.28
Environment	11	67	1.12
Incentive	9	58	0.97
People	6	50	0.84
Awareness	9	47	0.79
New	3	41	0.69
Parking	7	41	0.69
Less	4	38	0.64
Traffic	7	38	0.64

Table 6: Factor Loadings (Pattern Matrix) and Reliability Assessment

Factors and Indicators	Code	Mean	SD	IL	AVE	Composite Reliability	Alpha
Societal Benefits					**0.587**	**0.891**	**0.880**
Decommissioning of old vehicles is a step towards a better environment	DOV1	3.77	1.081	0.833			
Decommissioning old vehicles is a step towards creating awareness among users about the ill effects of using inefficient vehicles	DOV2	3.74	1.023	0.816			
One should then help society by giving up their old vehicles	DOV4	3.68	1.031	0.704			
Spreading the policy of ELV management across the country will help India in the long run.	DOV5	3.71	0.989	0.652			
ELV management will help in reducing vehicular pollution	DOV7	3.78	1.050	0.554			
Vehicle users will be interested in surrendering their old vehicles as per the ELV management policy	DOV3	3.35	1.018	0.548			
Industrial Benefits					**0.808**	**0.763**	**0.763**
ELV management will help the Indian economy in the long run by raising the GDP levels (due to the boost in the scrap industry and new purchase of vehicles)	DOV9	3.50	0.966	0.841			
The future for the scrappage industry is looking positive as it may help in the reuse and recycling of old vehicles (or parts of old vehicles)	DOV10	3.56	0.985	0.651			

Extraction Method: Maximum Likelihood.Rotation Method: Promax with Kaiser Normalization.
SD- Standard Deviation; IL-Item Loadings; AVE- Average Variance Extracted

Table 7: One-Sample Statistics and One-Sample Test

		N	Mean	Std. Deviation	Std. Error Mean
SOCBENF		878	3.67	0.82	0.028
INDBENF		878	3.53	0.88	0.029
	Test Value = 3				
				99% Confidence Interval of the Difference	
	t	Df	Sig. (2-tailed)	Mean Difference	Lower	Upper
SOCBENF	24.25	877	0.000	0.67	0.60	0.74
INDBENF	17.79	877	0.000	0.53	0.45	0.60

Figures

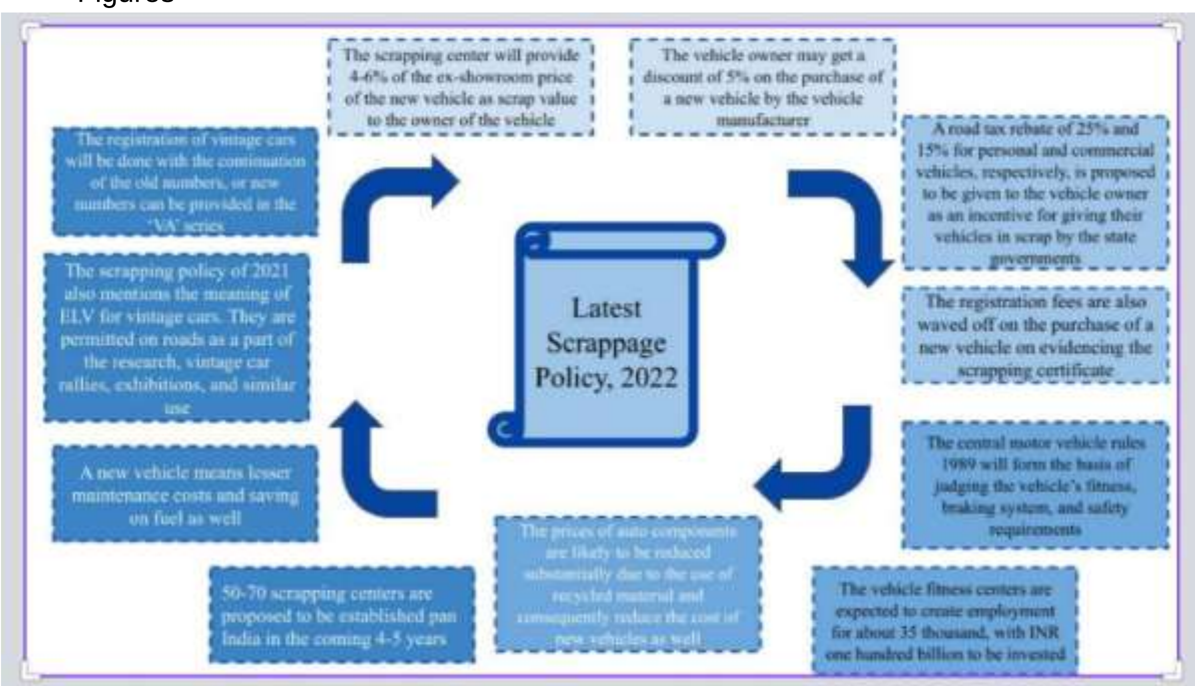

Figure 1: New Scrappage Policy - Highlights

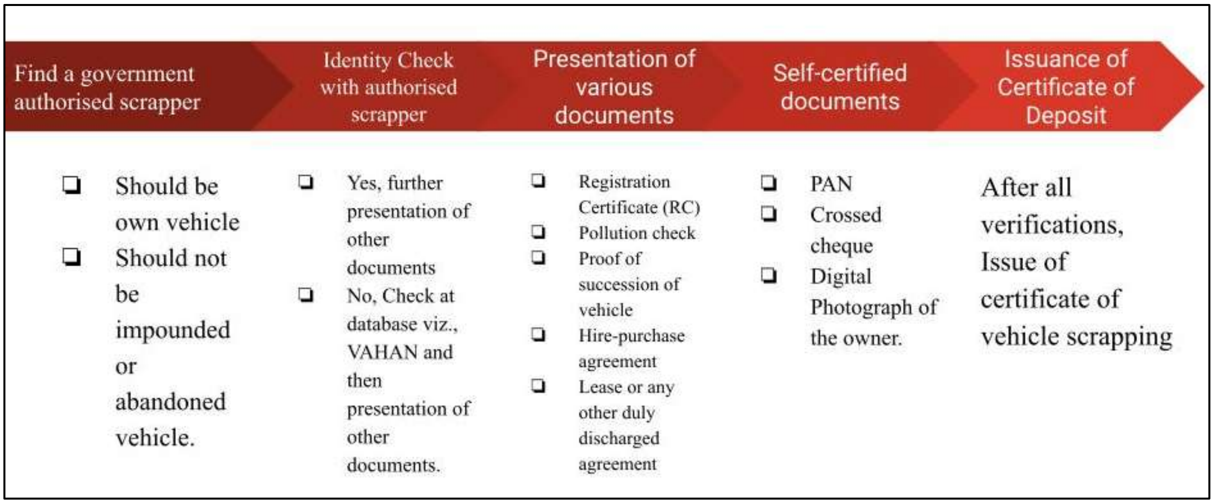

Figure 2: ELV Management Process

Figure 3: Word Clout of People’s Perception of ELV management

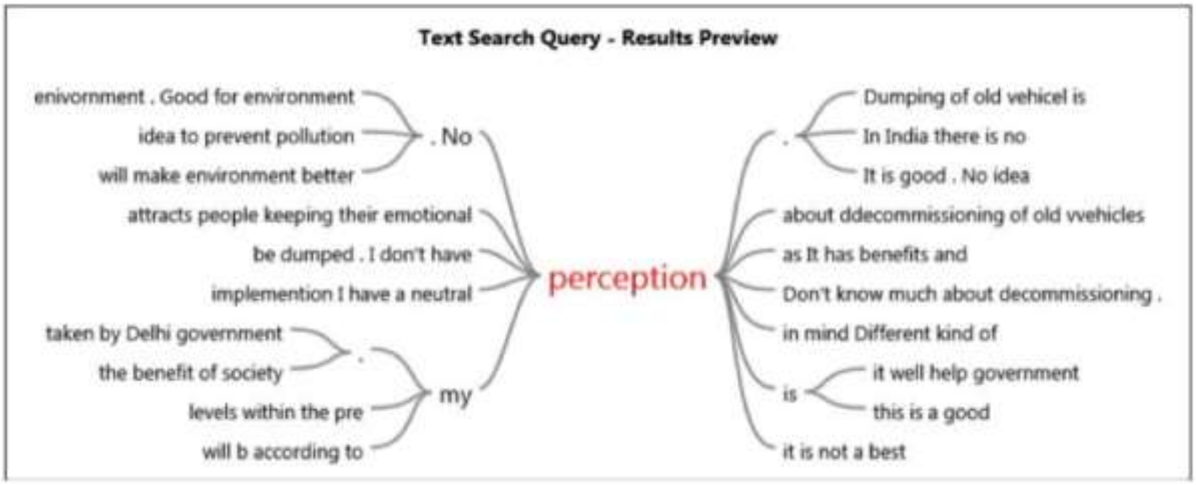

Figure 4: Treemap-Text Search Query of People's Perception of ELV Management