Lifecycle Assessment of the Social Behaviors of Automotive Product Recycling

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Abstract. A wide range of actors are engaged in the entire lifecycle of automotive products, and they may impact the recycling and reuse of these products through their social behaviours, including policy, perception, technology and environment. This paper investigates the social impact of automakers, dealerships/maintenance service providers, consumers, end-of-life vehicle recycling & dismantling enterprises and recycling enterprises, and explores how these actors matter to and impact product recycling through their social behaviours.

Keywords: Automobile · Lifecycle · Recycling and Reuse · Social Behavior

1 Introduction

By the end of September 2021, China's car parc amounted to 297 million units. There will be an estimated total of 400 million units in 2028 and 470 million in 2045. This means that a large number of end-of-life vehicles will emerge in future. In developed countries, about 4%–6% of the car parc are scrapped every year during the maturity of the automotive market. As per this ratio, the theoretical number of vehicles scrapped in China should be 15 million units every year [1–3].

2 Correlation Analysis of the Social Behaviors of Various Actors and Product Recycling

2.1 Automakers

Automakers play a pivotal role in the construction of the recycling system. Ecological design determines the environmental impact and dismantling convenience of automotive products. The openness of dismantling information is vital to backend enterprises as for whether they can dismantle vehicles easily and efficiently. Funding support is also great for the construction of the recycling system at the back end [4, 5].

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2.2 Dealerships/Maintenance Service Providers

Dealerships and maintenance service providers feature a mature and extensive network system, direct service to consumers, and short-term conditions for small quantities of storage, and hence can serve as recycling service outlets entrusted directly by the responsible parties for recycling entities. Further, maintenance service providers have an edge in reusing used parts and expanding the use of remanufactured parts for their built-in maintenance technology and free choice of parts. Therefore, dealerships and maintenance service providers mainly play the following roles amid the construction of the recycling system.ing or by third-party.

Firstly, they both can carry out vehicles and key parts collection activities as a recycling service outlet, entrusted by manufacturers and other responsible parties for recycling or third parties. Also, they can store used parts in small quantities for short term before transferring them to those service outlets for large quantities of storage or downstream integrated utilization enterprises, thereby bolstering the construction of the recycling system.

Secondly, maintenance service providers become a recycling channel for used parts as driven by market interests, and an anchor for secondary production and consumption by expanding the use of green parts and materials (remanufactured parts, used parts, water-based paints, etc.).

2.3 Consumers

As consumers are the only natural individual among other actors, their recycling and reuse behaviors matter less than those of other actors, and therefore they contribute the least share of recycling and reuse.

For consumers, the biggest stimulus for recycling is price, whether to scrap the vehicle or to reuse parts, and price almost has a direct impact. They showcase more of market-oriented behavior than social behavior.

2.4 End-of-Life Vehicle Recycling and Dismantling Enterprises

Compared to other actors, end-of-life vehicle recycling & dismantling enterprises reuse used parts at a very high degree as they are anchored in the recycling and reuse industry with recycling and reuse at the heart of their business. In the context of policy guidance, social cognition, technology upgrading and environmental protection, they are most susceptible and adaptable.

2.5 Recycling Enterprises

Although recycling enterprises do not play a prominent role in the construction of the recycling system, they still can produce visible environmental, social and environmental benefits.

3 Evaluation of Recycling Behavior

3.1 Methodology

The Analytic Hierarchy Process (AHP) was developed in the 1980s by Professor T.L. Saaty, a distinguished American operations researcher and professor at the University of Pittsburgh. AHP is a multi-objective decision-making method that combines qualitative and quantitative analysis and uses hierarchical decomposition to deal with complex decision problems, whereby multi-objective, multi-criteria decisions are turned into multi-level, single-objective pair-wise comparisons and then are processed mathematically.

The AHP has the basic principles as the principles of mathematics, decomposition, comparative judgements, and synthesis of priorities. Put it simply, the basic principles of AHP are applied to regard the complex issues as a large system, and divide the interconnected factors in an orderly hierarchy by analyzing various factors of the system; then experts are engaged to objectively judge the relative importance of factors in some given level; A mathematical model is created to calculate the relative importance of the factors in each level for priority; Finally, according to the priority, appropriate decisions and measures are determined. The AHP method generally consists of three steps.

(1) Developing a hierarchical model that describes the function or characteristics of the system: The hierarchy is the basis for the decision maker to quantify the decision-making process. After an in-depth analysis of the problem at hand, the factors included in the problem are divided into different levels.

(2) Constructing a judgement matrix: Experts construct a judgement matrix by comparing and scoring the factors according to their knowledge and experience. The value of the factors of the judgment matrix reflects people's perceptions of the relative importance of each factor (or merits, preferences, etc.).

(3) Single hierarchical ranking and its consistency test: With the judgment matrix constructed, the characteristic roots of the judgment matrix A are calculated, i.e. AW = the solution W of X. After normalization, the ranking weight of the relative importance of the corresponding factors at the same level to a certain factor at the previous level can be obtained, and this process is called single hierarchical ranking. In order to perform the consistency test of the single hierarchical ranking (or judgement matrix), it is necessary to calculate the consistency index CI = (−n)/(n − 1). When the random consistency ratio CR = CI/RI < 0.1, the results of the single hierarchical ranking are acceptable, or otherwise it is necessary to adjust the values of the factors of the judgment matrix.

To compare the influence of n factors Y = {y1, y2,…yn} on the same target, two factors yi and yj are taken at a time, and a ij represents the ratio of the degree of influence of yi to yj on the target, where the value of aij is determined by Saaty's 1–9 scale.

3.2 Evaluation

Based on the AHP calculation process, objectives are compared and weights are calculated for different actors in terms of policy guidance, social cognition, technology upgrading and environmental protection.

Table 1. Influence coefficient for automakers

	E1	E2	E3	E4
Weight	0.6071	0.0749	0.1394	0.1787

Table 2. Influence coefficient for dealerships/maintenance service providers

	E1	E2	E3	E4
Weight	0.6855	0.0608	0.1447	0.1089

According to the AHP calculation process, the target comparison and weight calculation are carried out on different subjects' policy guidance (E1), social cognition (E2), technological upgrading (E3) and environmental protection (E4) (Table 1).

(1) Automakers

$$\begin{bmatrix} - & E1 & E2 & E3 & E4 \\ E1 & 1 & 12 & 4 & 5 \\ E2 & - & 1 & 1/2 & 1/3 \\ E3 & - & - & 1 & 2/3 \\ E4 & - & - & - & 1 \end{bmatrix}$$

Where CI = 0.0277 and CR = 0.0220 < 0.1, the consistency results are acceptable.

(2) Dealerships/maintenance service providers (Table 2).

$$\begin{bmatrix} - & E1 & E2 & E3 & E4 \\ E1 & 1 & 8 & 6 & 7 \\ E2 & - & 1 & 1/2 & 1/3 \\ E3 & - & - & 1 & 2 \\ E4 & - & - & - & 1 \end{bmatrix}$$

Where CI = 0.0548 and CR = 0.0435 < 0.1, the consistency results are acceptable (Table 3).

(3) Consumers

$$\begin{bmatrix} - & E1 & E2 & E3 & E4 \\ E1 & 1 & 5 & 4 & 3 \\ E2 & - & 1 & 1/3 & 1 \\ E3 & - & - & 1 & 1/2 \\ E4 & - & - & - & 1 \end{bmatrix}$$

Where CI = 0.0945 and CR = 0.0750 < 0.1, the consistency results are acceptable (Table 4).

Table 3. Influence coefficient for consumers

	E1	E2	E3	E4
Weight	0.5592	0.1021	0.1572	0.1815

Table 4. Influence coefficients for end-of-life vehicle recycling & dismantling enterprises

	E1	E2	E3	E4
Weight	0.4738	0.0753	0.2449	0.2060

Table 5. T Influence coefficient for automakers for recycling enterprises

	E1	E2	E3	E4
Weight	0.2521	0.0634	0.4691	0.2154

(4) End-of-life vehicle recycling & dismantling enterprises

$$\begin{bmatrix} - & E1 & E2 & E3 & E4 \\ E1 & 1 & 7 & 2 & 2 \\ E2 & - & 1 & 1/4 & 1/2 \\ E3 & - & - & 1 & 1 \\ E4 & - & - & - & 1 \end{bmatrix}$$

Where CI = 0.0170 and CR = 0.0135 < 0.1, the consistency results are acceptable (Table 5).

(5) Recycling enterprises

$$\begin{bmatrix} - & E1 & E2 & E3 & E4 \\ E1 & 1 & 5 & 1/2 & 1 \\ E2 & - & 1 & 1/5 & 1/4 \\ E3 & - & - & 1 & 3 \\ E3 & - & - & - & 1 \end{bmatrix}$$

Where CI = 0.0307 and CR = 0.0244 < 0.1 the consistency results are acceptable.

To sum up, the combined impact of the influence factors on the actors can be derived, as shown in Fig. 1.

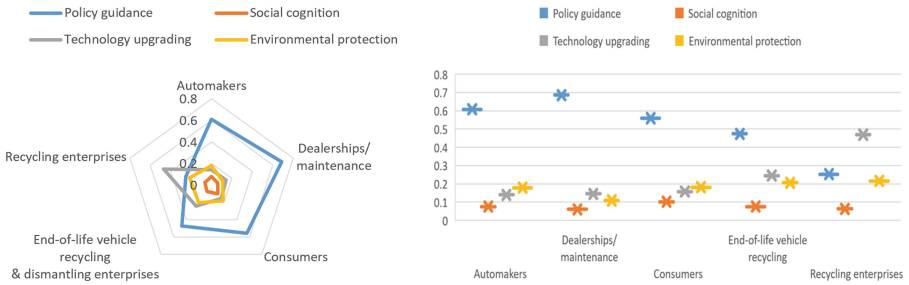

Fig. 1. Glimpse of the influence factors of all actors in radar-box plot

4 Comprehensive Analysis of Factors Influencing Recycling Social Behaviors

4.1 Policy Guidance Matters More in the Early Courses of Automotive Product Lifecycle

It is clear to see that policy guidance is prevalent in the industry, and vital to all actors as driven by certain objectives and incentives. In the early courses of the lifecycle, policy guidance is the main influence factor for actors to engage in recycling. Manufacturers, for instance, bear the main duty to implement the Extended Producer Responsibility and hence engage in recycling.

Policy guidance is not only the most important of the factors, but also influences the coefficients of the other factors and plays a decisive and fundamental role in the four social behavior factors.

4.2 Raising Social Cognition of All Actors

Social cognition is actually each group's social responsibility cognition for recycling, i.e. a group's commitment to contribute to the sustainable social development by taking social and environmental responsibilities related to recycling while realizing its own value and creating profits.

The analysis results suggest that social cognition has a small impact on all courses of the lifecycle, and is the weakest of the four influencing factors.

It is now generally accepted that social cognition is not directly related to the increase in economic value of an enterprise, and may even reduce revenue by increasing corporate costs. However, with the development of China's economy and society, social responsibility has gradually become a focus and a hot topic, and more and more enterprises are called upon to pay attention to corporate social responsibility (CSR). It is also found that CSR practices can greatly boost the economic, social and environmental performances of enterprises. Looking ahead, all actors will gradually raise their focus on social cognition, especially automakers, who play a leading role in the entire automotive industry chain, and social cognition will become an important factor affecting the value of automotive brands.

4.3 Environmental Protection Not Yet Being the Primary Driver

Environmental protection is the most basic requirement for all actors in China, and also a very important period in China's environmental protection history. During this period, China's environmental protection has undergone radical reforms and adjustments in terms of management strategies, systems, ideas and objectives before entering a substantial stage. However, environmental protection and social cognition are similar in that they are not directly driven by the market, and can only be indirectly guided by economic values or policy mandates unless otherwise engendered by actors' self-awareness.

4.4 Upcoming Technology Upgrading

In the final processes, especially the recycling process, technology upgrading outweighs policy guidance, and this is the only process in which policy guidance is not the dominant factor. Throughout the entire automotive industry chain, the recycling process remains at a low technology level. With recycling as their main business, recycling enterprises are doomed to be impacted by technology, which in turn reflects the competence of such enterprises. For other enterprises, due to the low profits of vehicle recycling and dismantling, recycling and dismantling enterprises have taken an extensive approach and earn money by selling scrap iron and steel, so the direct influence factor is the number of vehicles recycled rather than the technology level. For manufacturers, increasing the recycling rate is one of the main metrics for the implementation of the producer responsibility, but China's Extended Producer Responsibility has not yet been fully implemented and hence has not received enough attention from manufacturers.

5 Conclusions

5.1 Reinforcing the Values of Reusing Our Resources

A sound and effective recycling system should be well attuned to the current social values of resource recycling and reuse. Since it is believed that China boasts a vast territory and rich resources, the first access to our resources is by exploiting natural resources, and the concept of recycling came out later and has not yet stood firm. So, for automobiles, the spotlight falls upon manufacturing and consumption throughout the society, with the final recycling process being less concerned. Moreover, the perception of the social attributes of automotive products is also significant. Despite a growing number of vehicles in China, it is still a great deal for a family to buy a vehicle. A majority of users hold that automotive products are valuable personal property only second to housing, and that even vehicles in poor condition still have a greater economic value, regardless of their social attributes as a waste. The social values of a nation are not constant but advance with the productivity among others. Similarly, for a society as a whole, it may take a generation or even several generations to change social values.

5.2 Establishing the Extended Producer Responsibility for Automotive Products

Automakers are an important part in the entire lifecycle of the vehicle, but due to the lack of applicable laws and regulations, Chinese automakers pay insufficient attention to the recycling of vehicles. By now, only a few have well-established recycling management system, automotive product eco-design system and green supply chain management system at hand. Compared to foreign management experience, China still needs to strengthen the management of automotive product recycling from the source. Despite the endeavors by a few automakers in recycling, on the whole, domestic manufacturers rarely consider recycling during product design and material selection, and due to the lack of policy and market incentives, automakers are less involved in the process of recycling, dismantling and reuse of parts and materials of end-of-life vehicles.

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