Research on Vehicle Survival Rule Based on Service Life Distribution

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Abstract. This paper analyzes the distribution law of automobile service life through big data and studies the survival rate of automobiles. The Weibull distribution model is used to fit the data of different types of automobiles, revealing that the survival rate of automobiles decreases with the increase in years of use. Comparing the data from 2022 and 2016, it is found that except for heavy-duty trucks, the survival ratio of other types of vehicles has increased in the same year. The survival life of new energy vehicles is usually within 10 years, which is significantly lower than that of traditional vehicles. These research results provide an important basis for automobile manufacturers and policymakers, helping to improve the durability and environmental benefits of automobile products.

Keywords: Automobile, survival rate, heavy trucks, battery electric vehicle (BEV), service life

1 Introduction

In recent years, China has adopted a series of incentive measures in the prevention and control of motor vehicle pollution, which has accelerated the elimination of old and high-emission vehicles, thus changing the law of automobile survival [1]. At present, there are studies on the survival law of automobiles mainly through statistical analysis methods to predict and evaluate the survival rate of automobiles, while some studies have conducted in-depth discussions on the survival rate of specific types of automobiles or specific use scenarios [2,3,4]. These studies are not only innovative in methodology, but also reflect the concern and reflection on the development and application of the field of automotive survival in the selection of application scenarios. However, the research on specific models, especially trucks, sub-function types and usage scenarios is not enough. Therefore, it is necessary to study and update the survival rate of vehicles. The purpose of this paper is to analyze the distribution law of vehicle service life, deeply explore the changing trend of vehicle survival rate and its deep causes, and provide scientific basis for automobile market prediction and planning.

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2 Research Methods

2.1 Research Data

Based on the historical ownership data (divided into 0-30 years of vehicle age) and sales data from Automotive Data of China Co., Ltd., a mathematical model is used to establish a database for the survival rates of passenger cars and commercial vehicles. Based on this data, a connection between sales volume and ownership is established. The data fields include different types of vehicles and fuel types.

Table 1. Model classification standards.

Vehicle model	Subdivision type	Definition
Passenger vehicles	-	Micro, Small, Compact, Medium, Mid-Large, Large
Commercial vehicles	Bus	Large bus (Length >10 meters)
		Medium bus (7 meters < length ≤ 10 meters)
		Small bus (3.5 meters < length ≤ 7 meters)
	Truck	Heavy trucks (maximum designed gross weight >14 tons)
		Medium trucks (6 tons < Maximum Design Gross Vehicle Weight ≤14 tons)
		Light trucks (1.8 tons < maximum designed total mass ≤6 tons)
		Micro trucks (maximum designed gross mass ≤1.8 tons)

Note: Vehicle type classification refers to the Ministry of Public Security standards and fuel consumption standards, close to the vehicle enterprise product layout and certification, and combined with market usage habits to further subdivide.

2.2 Research Model

Methods for calculating vehicle survival laws include statistical models, reliability engineering methods, machine learning and big data analysis, physical models, and empirical formulas and criteria [5.6]. These methods have their own characteristics, such as statistical models using life distribution models and regression analysis, reliability engineering methods including fault tree analysis and failure mode and impact analysis, machine learning methods including regression algorithms, classification algorithms and deep learning, physical models involving mechanical and thermodynamic analysis, empirical formulas and criteria are calculated based on historical experience and industry standards [7].

Among them, Weibull distribution is more suitable to describe the vehicle survival law, because it has flexibility, adaptability, good data fitting and theoretical support [8]. The flexibility of Weibull distribution enables it to adapt to different life characteristics, and its parameters can be adjusted to fit the actual data. Its adaptability enables it to better describe the characteristics of failure rate changing with time, which accords with the characteristics of vehicle life changing with time [9]. In addition, Weibull distributions are generally good at fitting lifetime data, especially for trends of gradual increase or decrease; Finally, in the field of reliability engineering, Weibull distribution has been widely studied in theory and applied in practice, and its validity and reliability in describing life data have been fully verified. Therefore, combining these characteristics, Weibull distribution is more suitable to describe the law of automobile survival in the Chinese market [10].

Weibull function,

$$y = e^{-(\frac{x}{\lambda})^k} \tag{1}$$

Where, x is the number of years of the vehicle; λ>0 is the proportion parameter, k>0 is the shape parameter, both of which are determined by vehicle technology, market characteristics, user characteristics and other factors, and can be obtained through big data statistical analysis.

3 Automobile Survival Rule Analysis

Based on the historical ownership and sales data, the survival conditions of registered vehicles in each year were counted respectively, and the survival conditions of each vehicle age were fitted with a two-parameter Weibull distribution model, which was modified and verified by scrap volume to obtain the survival laws of vehicles.

According to the statistical analysis of ownership and sales data, the average life of passenger cars in 2022 is the highest, with an average life of about 14 years. The passenger car is generally higher than the truck, and the truck shows the characteristics of the smaller the model, the longer the life.

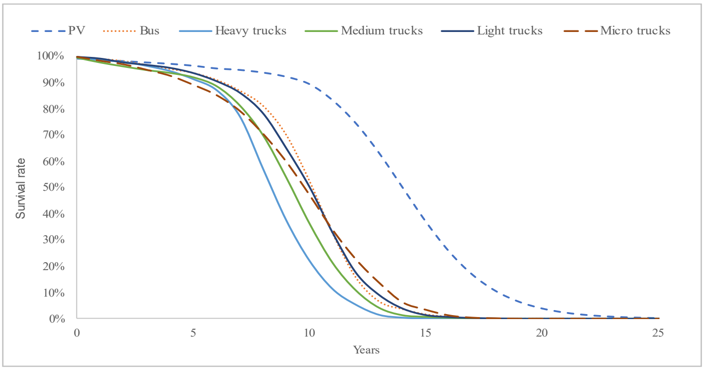

Fig. 1. Survival curves of various types of vehicles in 2022.

3.1 Survival Rules of Passenger Vehicles

Compared with 2016, the 10-year survival rate of passenger cars in 2022 has decreased, and the survival rate after 10 years has improved significantly [11]. By fuel type, the service life of traditional fuel vehicles is extended, the average service life is more than 14 years, and the survival rate is higher than 90% in 10 years; The average service life of BEV is about 7 years due to battery decay. With the upgrading of technology, the service life of BEV is expected to gradually extend in the future. Plug-in hybrid vehicle (PHEV) service life is between the traditional fuel vehicle and pure electric; Compressed natural gas vehicle(CNG) is mainly a taxi, with high loss and mandatory scrappage life requirements, so its average service life is 6-7 years, and the survival rate is the lowest among all fuel types.

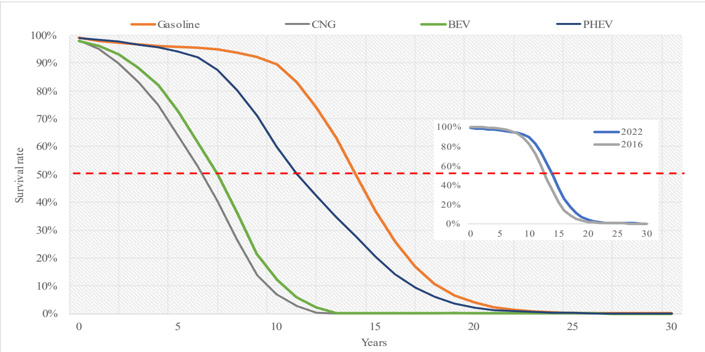

Fig. 2. Survival rule curve of passenger vehicles by fuel type in 2022.

3.2 Survival Rules of Commercial Vehicles

Compared with 2016, the overall average service life of commercial vehicles in 2022 has increased by about 1 year, and the decline in survival rule after 5 years of use has slowed down. The halving of the survival rate of commercial vehicles in 2022 corresponds to 10 years of vehicle age, which is 1 year higher than in 2016.

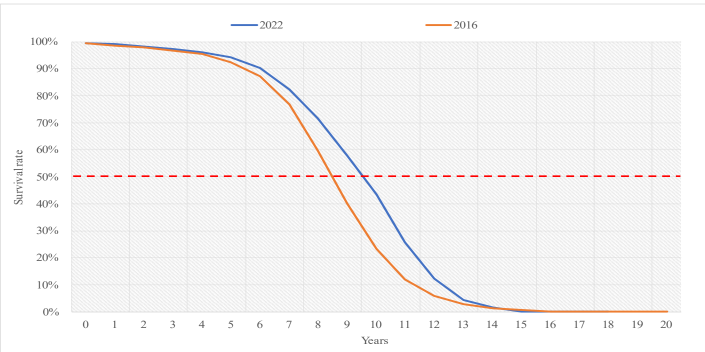

Fig. 3. Comparison of survival curves of commercial vehicles in 2022 and 2016.

In 2022, the survival rate of trucks is about 9.5 years old, and the survival rate drops rapidly from the sixth year. Compared to 2016, survival rates in 2022 were lower before the fifth year and higher after.

In 2022, the survival rate of bus is about 10.2 years old, and the survival rate drops rapidly from the 7th year. Compared to 2016, survival rates in 2022 were flat until the fourth year and higher thereafter.

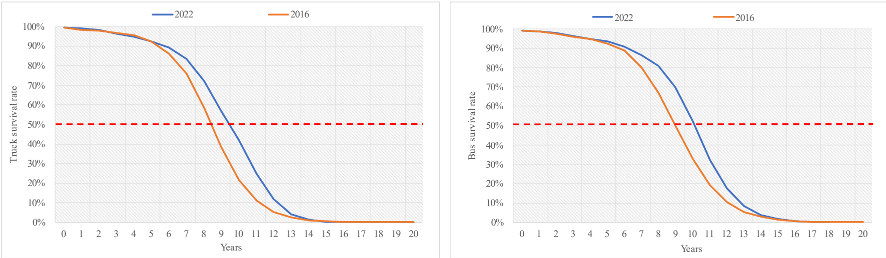

Fig. 4. Comparison of survival curves of commercial vehicles in 2022 and 2016.

In the context of technology iteration, the overall average life of medium, micro and light trucks in 2022 increased by 1-2 years compared with 2016, and the survival rate declined slowly, and the survival rate in the first 5 years of use decreased slightly compared with 2016. However, the survival rate of heavy trucks was slightly lower than that of 2016.

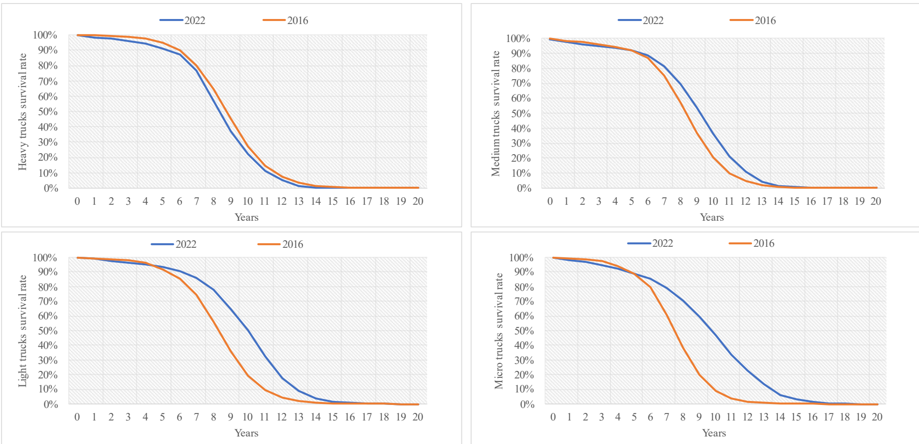

Fig. 5. Comparison of survival curves of different types of trucks in 2022 and 2016.

Due to the special nature of heavy trucks, it is the focus of our discussion next. In 2016-2020, heavy trucks have experienced the policy guidance stage of "blue Sky Defense War", such as the centralized elimination of three national vehicles, the change of weighing charges to axis charges and the upgrade of national six, and the early elimination and replacement of various models, and the survival rate has decreased. In 2022, due to overdraft brought by demand in advance and reduced enthusiasm for car replacement under the impact of the epidemic, the survival rate in each year has slightly increased, but it is still lower than in 2016 and 2018.

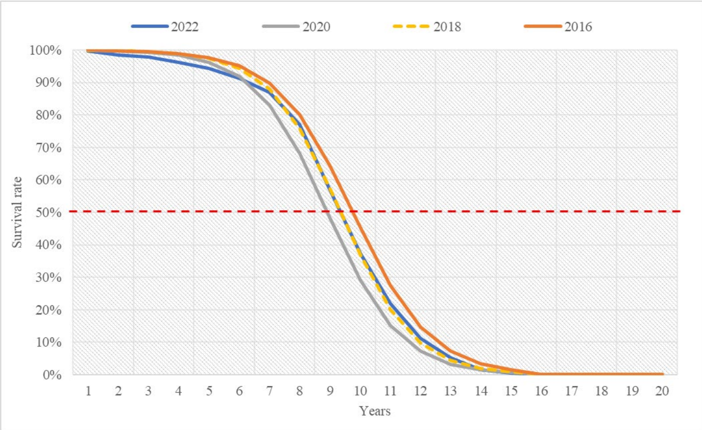

Fig. 6. Comparison of survival curves of heavy trucks in different years.

With the improvement of logistics environment and the decline of vehicle capacity, the demand space for trucks is reduced, and tractor trucks with higher transport efficiency can better adapt to the development needs of the industry. The trend of traction of highway logistics will become more obvious. Compared with ten years ago, the growth rate of 167%, the frequency of use of tractor trucks is increased, and the average vehicle age and survival rate of each year are relatively reduced. In addition, special trucks and dump trucks serve more infrastructure or industrial production, and centralized procurement is more, showing periodic changes, so the survival rate shows a stable decline in the age of the vehicle.

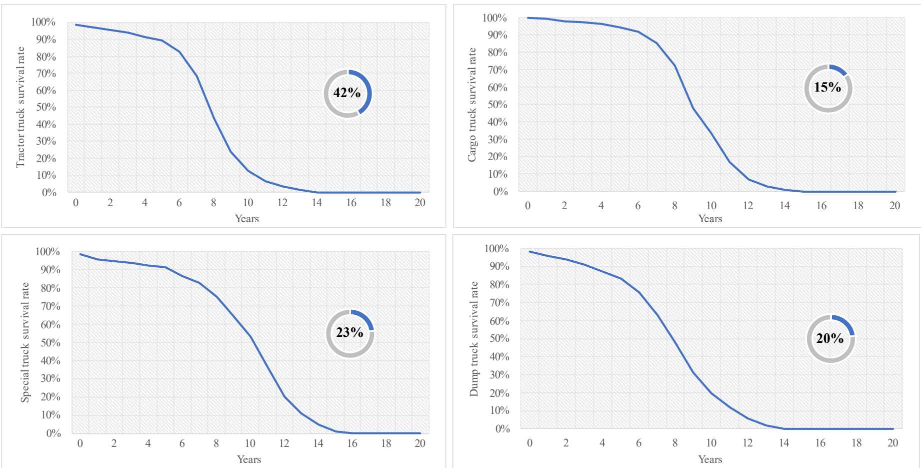

Fig. 7. Survival curve of heavy trucks by functional use in 2022.

With the intensification of competition in the freight market and the promotion and application of new energy tractors, the adaptability advantages of 6x4 tractors in multiple scenarios have been improved, and the overloading management and the implementation of the axle charging policy have further pulled up the capacity advantages of six-axis tractors, and 6×4 heavy trucks has become the mainstream of the market. In addition, trucks are further concentrated in urban and intercity transportation, and two-axle trucks have higher flexibility and low toll costs. Under the comprehensive influence, the survival rate of 6×4 and 4×2 models remained high.

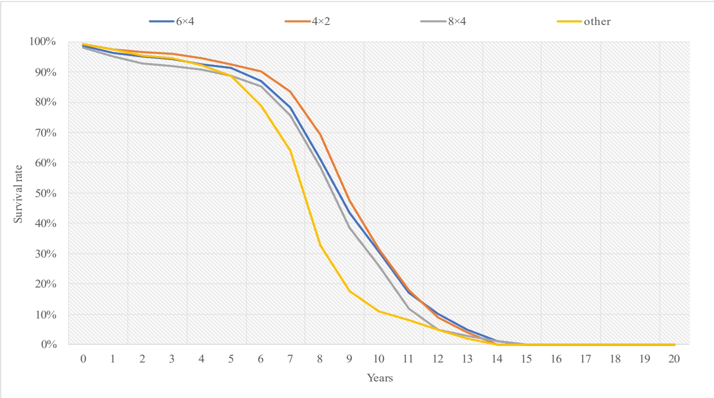

Fig. 8. Survival curve of heavy trucks by functional use in 2022.

China's heavy trucks fuel type is dominated by diesel, accounting for about 93% of the total inventory in 2022, the survival rate of diesel heavy trucks began to decline rapidly in the eighth year, and the survival rate halved corresponding to the vehicle age of 8.5 years. In recent years, the number of new energy heavy goods has continued to grow, but the technical maturity needs to be improved, the average vehicle age is short, and the survival rate shows a steady downward trend before scrapping.

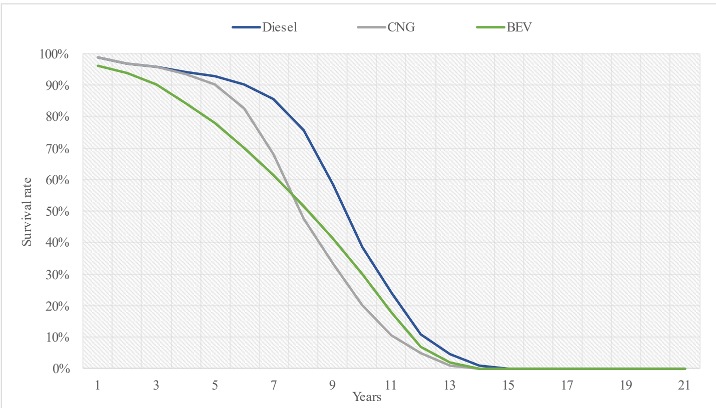

Fig. 9. Survival curve of heavy trucks by fuel type in 2022.

4 Conclusion

In this study, authoritative data are used to measure and compare the changes of vehicle survival laws. The average life of passenger vehicles is 14 years, 4 years longer than that of light minivans and 5.5 years longer than that of heavy trucks. The survival rate of commercial vehicle segments is strongly related to the operation attributes, frequency of use, operating mileage, etc. Specifically, the survival rate of passenger cars is 10.2 years, light trucks is 10 years, medium trucks is 9.5 years, and heavy trucks is 8.5 years. The average service life of commercial vehicles in 2022 is about 1 year higher than that in 2016, and the product capacity is steadily improved. Under the influence of policies such as the elimination of old vehicles, high-emission vehicles and the upgrading of the Sixth National Government, heavy trucks are eliminated and replaced in advance, and the survival rate is reduced. The development of tractors to multi-axis, dump trucks and trucks to two-axis development, promoting the survival rate of 6×4, 4×2 models in heavy trucks to maintain a high; The survival rate of new energy heavy trucks is faster than that of other fuel types, which is related to the short service life of the power battery and the status quo that most of them are used in closed scenarios. This study is applicable to the matching analysis of vehicle survival rate in the context of technological progress and new energy market expansion. The research results can provide reference for market forecast and low-carbon development planning. Subsequent studies may consider the differences in vehicle survival laws between provinces and cities, as well as the effects of mandatory scrappage and early replacement policies on the survival curve.

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