Based on the Patent Index Method and S Curve Method Prediction Analysis of Pure Electric Vehicle Life Cycle

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Abstract. In order to grasp the direction of pure electric vehicle technology innovation in strategic macro, this paper retrieves the domestic patents in the field related to pure electric vehicles, using the patent index method and S-curve method to analyze the life cycle of pure electric vehicle technology. It is clear that the pure electric vehicle technology in China is in the mature stage of the technology life cycle, In view of the development stage and development trend of pure electric vehicle technology in China, this paper provides patent strategies for related enterprises from the perspective of patent strategy. The combination of patent indicator method and s-curve method can predict the technology life cycle more accurately, providing a feasible analytical method for the identification and prediction of the patent technology life cycle.

Keywords: Pure Electric Vehicles, Patent Index Law, S Curve Technology, Technology Life Cycle

1. Introduction

With the development of society and the arrival of the era of big data, the information technology and patent database have been continuously developed, obtaining the intelligence information hidden behind the data through patent analysis is beneficial to the formulation of enterprise strategy and the development of technology. China in "Made in China 2025" proposed that China's auto industry should vigorously promote and innovate energy-saving new energy vehicles. Pure electric vehicles have become a hot spot in the research and development of new energy vehicles because of their advantages of low pollution and low noise [5].

At present, more and more scholars analyze the development of domestic pure electric vehicle industry from the perspective of patent. There are many approaches to patent analysis, such as spatial distribution analysis, technology matrix analysis and technology life cycle analysis [1, 2]. Among them, the research on technology life cycle mainly focuses on the technology level. With the increasingly fierce competition in automobile industry, relevant enterprises also need to grasp the current situation and development trend of pure electric vehicle technology strategically [1-5].

In this paper, patent index method and s-curve method are combined to analyze the life cycle of pure electric vehicle technology in China, reveals the current development situation and future
development trend of pure electric vehicle technology in China, and finally provides relevant patent strategies for related enterprises.

2. Technology life cycle analysis
Technology life cycle refers to the development process of a technology, the development of any technology must follow a certain objective law, that is, through research from the emergence, to the technical application of products, then products into the market, and finally out of the market. The technology life cycle is divided into four stages: technology introduction stage, technology growth stage, technology maturity stage and technology decline stage. In different periods, different enterprises have different r&d strategies. So we say that the analysis of technology life cycle can clarify the stage of technology development, so as to help the group of enterprises to study the future development trend and formulate appropriate technology research and development strategy [4].

2.1. Patent index method
The patent index method calculates the historical values of four indicators: technology growth rate \( v \), technology maturity coefficient \( \varepsilon \), technology aging coefficient \( \beta \) and new technology characteristic coefficient \( N \), generates a chart and observes the change trend of the data, so as to judge the life cycle of the technology (see table 1).

| phase          | Technical growth rate | Technology maturity factor | Technical Aging Coefficient | New technology characteristic coefficient |
|----------------|-----------------------|---------------------------|----------------------------|-------------------------------------------|
| Introduction period | ↑Small growth rate     | ↑                         | ↑                          | ↑                                        |
| Growth period   | ↑Significant growth   | ↑                         | ↑                          | ↑                                        |
| Mature stage    | ↓                     | ↓                         | ↑or constant               | ↓                                        |
| Recession       | ↓                     | ↓                         | ↓                          | ↓                                        |

The calculation formula of each index is as follows:

\[
v = \frac{a}{k}; \varepsilon = \frac{a}{a+b}; \beta = \frac{a+b}{a+b+c}; N = \sqrt{a + \nu}
\]

In the above formula, \( k \) is the total number of invention patents applied in the technology field in the past five years, \( a \) is the number of technical invention patent applications, \( b \) is the number of utility model patent applications, and \( c \) is the total number of design patent applications (all the above applications are authorized), the value of \( v \) is increasing, indicating that the technology is in the bud or growth stage; the \( \varepsilon \) value decreases for several consecutive years, indicating that the technology is becoming more mature; If the value of \( \beta \) increases for several consecutive years, it indicates that the technology tends to be obsolete; the size of \( N \) value reflects whether the characteristics of the new technology are increasing or showing signs of aging.

2.2. Method of S curve
The s-curve method mainly includes two types: Logistic curve and Gompertz curve, the former is symmetric, the latter is asymmetric. Among them, the Logistic curve has a wide range of applications in practice, and this curve can be expressed by a function about \( t \):

\[
y = f(t) = \frac{k}{1 + ae^{-\beta t}}
\]
In formula (2), \( y \) represents the cumulative number of patent applications for a technology, \( k \), \( a \), and \( b \) are constants, and \( t \) is time. Using the patent application data of a technology to fit a Logistic curve, you can judge the various stages of its life cycle.

\( k \) is the maximum value of \( y \), \( f(t_{10}) = 10\%k, f(t_{50}) = 50\%k, f(t_{90}) = 90\%k \), It is generally believed that before \( t_{10} \) is the introduction period, the growth period is between \( t_{10} \) and \( t_{50} \), the maturity period is between \( t_{50} \) and \( t_{90} \), and the decline period is after \( t_{90} \). This paper uses the collected patent data and matlab software to fit the logistic curve of pure electric vehicle technology for life cycle analysis[7].

3. Research on technology life cycle of pure electric vehicle

3.1. The data source

This paper takes the database of the state intellectual property office of China as the data source, using the SooPAT search platform, adopt "keyword" search method, the retrieval formula is "pure electric vehicle or BEV", search time up to December 31, 2019, the statistical scope is Chinese invention patent, utility model and appearance design, It obtained 7044 patent data in the field of pure electric vehicle technology in China, and sorted out the number of applications for various patents in the field of pure electric vehicle technology in China from 1991 to 2019. See Table 2 for details

| year   | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 |
|--------|------|------|------|------|------|------|------|------|------|------|
| Number of invention applications | 0    | 0    | 0    | 1    | 2    | 1    | 3    | 4    | 3    | 8    |
| Number of utility model applications | 1    | 0    | 1    | 2    | 9    | 3    | 6    | 11   | 11   | 24   |
| Number of design applications | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 1    | 0    |      |

| year   | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 |
|--------|------|------|------|------|------|------|------|------|------|------|
| Number of invention applications | 9    | 14   | 48   | 61   | 61   | 90   | 145  | 179  | 158  | 111  |
| Number of utility model applications | 74   | 115  | 166  | 209  | 193  | 228  | 296  | 384  | 412  | 424  |
| Number of design applications | 5    | 20   | 5    | 14   | 5    | 21   | 34   | 45   | 76   | 66   |

3.2. The data analysis

According to the calculation formula of patent index method and patent data application quantity in table 2, the trend chart of four characteristic parameters is calculated.
**Figure 1.** Variation trend of technology growth rate and technology maturity coefficient of pure electric vehicles in China from 2004 to 2019

As shown in figure 1, the technical growth rate $v$ generally presents a small inverted "v" shape. Before 2012, the $v$ trend curve showed an upward oscillation. According to the analysis of the number of invention patent applications in table 2, at this stage, the $v$ value of pure electric vehicles grew slowly and entered the introduction period; it reached a small peak in 2012, indicating that there were breakthroughs in the field of pure electric vehicle technology during this period, and these breakthroughs brought the technology field to a rapid growth stage; However, after 2012, the value of $v$ dropped sharply, and the rate of decline gradually slowed down after 2014. So far, the value of $v$ has been oscillating and declined, indicating that China's pure electric vehicle technology is slow to update and lacks breakthrough technology.

The change trend of the technology maturity coefficient $ε$ is generally U-shaped. Before 2010, $ε$ showed an oscillating downward trend, indicating that China's pure electric vehicle technology had been in a slow development stage before this; from 2010 to 2012, the $ε$ value increased rapidly, and China's pure electric vehicle technology entered a rapid growth period; Slow rise of $ε$ from 2012 to 2016, which indicates that the technology continues to develop; after 2016, it shows a decreasing trend, indicating that the technology has entered the mature period.

![Technological aging coefficient](image1)

![New technology characteristic coefficient](image2)

**Figure 2.** Variation trend of technological aging coefficient and new technology characteristic coefficient of pure electric vehicle in China from 2004 to 2019

Before 2007, the design patent of pure electric vehicle technology in China was almost zero, so the aging coefficient of this technique is always close to 1, and then it oscillates, technical aging coefficient reached its lowest point in 2011; from 2007 to 2011, the value of $β$ was generally lower, indicating that the technology was updated at this stage; from 2011 to 2014, the value of $β$ continued to increase, which means that the technology is increasingly obsolete, and continued to decline after 2014.

The characteristic coefficient $N$ of new technology is similar to the change trend of technology growth rate $v$ in general, before 2012, the $N$ value oscillated and increased, indicating that the technology had not yet reached the mature stage; after 2012, it shows a slightly decreasing trend of oscillation, but it is in line with the overall trend of the curve, indicating that the new technology characteristics of China's pure electric vehicle technology are strong and have not yet reached the decline period.

The data in table 2 is input into matlab year by year, and the $S$ curve obtained is shown in figure 3, the ordinate is the cumulative number of patents, the abscissa is the year -2003, the key data points obtained are shown in table 3. From this, it can be concluded that the pure electric vehicle technology in China entered the growth stage in 2012, the dividing point between growth stage and maturity stage in 2016, and is expected to enter the decline period in 2023; in the end, the maximum cumulative
application for this technology patent was 6,192. At present, the development space of pure electric vehicle technology is gradually shrinking, and the activity of technological innovation is slowing down. With the gradual saturation of the market, the growth rate of the number of participating enterprises is slowing down, and the technical competition in the domestic market is still becoming fierce [8].

![Figure 3. Pure electric car S curve](image)

Table 3. Key data points of S curve of pure electric vehicle technology in China

| project | L/number | t_{10}/year | t_{50}/year | t_{90}/year |
|---------|----------|-------------|-------------|-------------|
| Data values | 6192 | 2012 | 2016 | 2023 |

3.3. The results of the analysis

By comparing the analysis results of the above two methods, it can be found that the two analysis results are basically consistent, and it can be concluded that the life cycle of China’s pure electric vehicle technology is as follows: At the beginning of the 20th century, China's pure electric vehicle technology began to sprout, after about 12 years of technology introduction period, it entered the growth period in 2012, just entered the maturity period in 2016, will continue to be in the maturity period from 2017 to 2022, and is expected to enter the recession period in 2023. According to the current stage and future development trend of China's pure electric vehicle technology, the patent strategy Suggestions for China's relevant enterprises are as follows:

1. According to the current situation, tailored for their own development road

At present, the pure electric vehicle technology has just entered the mature period, enterprises with strong innovation ability can seize the last opportunity to accelerate the development of new technologies and try to create new market demand; enterprises with medium innovation ability should strengthen the cooperation strategy and improve the excellent technology learned from advanced enterprises according to their own reality; enterprises with weak innovation ability can choose to follow the strategy and adopt the technology implemented by most enterprises.

2. Strengthen cooperation with research institutions and exchanges between enterprises

Relevant enterprises should actively carry out industry-university-research cooperation with scientific research universities and research institutions, especially enterprises with medium innovation capacity should actively seek cooperation for technological innovation and technology transfer, and finally realize the transformation of patent achievements.

3. Make full use of government subsidy policies
The report of the 19th National Congress of the Communist Party of China clearly proposed to strengthen the creation, protection and use of intellectual property rights. Local governments responded to the call of the Party Central Committee and issued patent policies and fund management measures to promote technological innovation in enterprises. Enterprises related to pure electric vehicles can pay more attention to relevant policies issued by the government and actively apply for appropriate supporting projects according to their own conditions.

4. Conclusion
This article uses the patent index method and S-curve method to analyze the life cycle of pure electric vehicle technology in China, the time nodes of the period of introduction, growth, maturity and decline of pure electric vehicles are clarified, and some Suggestions are put forward for the formulation of innovation strategies of related enterprises according to the current stage of pure electric vehicles in China. The future research can find the breakthrough point for the pure electric vehicle technology which has just entered the mature stage through the analysis of the specific technology, so as to avoid its premature decline.

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