Optimization Strategies for Enterprise Production and Development under the Guidance of New-Quality Productivity

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ABSTRACT

With the widespread application of new quality productivity in production and service processes, whether manufacturing enterprises can seize opportunities and avoid risks in the increasingly fierce market competition and technological changes plays a crucial role in the development of enterprises. Based on this, this paper constructs a model using the Analytic Hierarchy Process (AHP) to comprehensively evaluate different technologies based on their scores in these aspects. Additionally, Operations Research methods are used to establish a new technology assessment model to promote the optimization of enterprise development strategies. Then, regarding the risks existing in the process of introducing new technologies, this paper choose to establish a quantitative evaluation model to reduce risks, and finally formulate a long-term plan for technological updates and business development for the enterprise.

Keywords: Multi-Stage Efficiency Improvement Model; Technology Maturity; SWOT Analysis; AHP

1 INTRODUCTION

In today's increasingly competitive global marketplace, manufacturing companies are challenged to select the right new quality productivity technologies to achieve long-term sustainability and competitive advantage. This paper aims to explore how to choose the most suitable technology for investment and application among diversified new technologies, and uses the HP method to design a comprehensive evaluation system, which refers to the recommendations of Brynjolfsson and McElheran (2021), and fully considers the comprehensive impact of technology on enterprise production efficiency, product quality, cost savings, and market competitiveness [1]. This evaluation system can not only help enterprises fully understand the potential value and risks of different technologies, but also provide an important reference for enterprises to formulate long-term technology renewal and business development plans. Furthermore, this paper designs an effective technology fusion scheme in detail, based on the data-driven production system integration framework proposed by Rose Clancy et al. (2023), emphasizing the importance of data integration and process automation [2]. At the same time, this paper also discusses the technical, market, and management risks in the process of introducing new technologies, and proposes corresponding management strategies based on Delong Zhu's risk assessment model [3]. Finally, this paper combines the innovation strategy model of Yu Wenling and Lipai Zhang (2023) to formulate a long-term plan for enterprises to adapt to future market demand and technological change, emphasizing the importance of technology iteration, market expansion, and product innovation [4]. Through the above research, this paper provides a comprehensive decision-making and operational framework for manufacturing companies to achieve their long-term sustainability and competitive advantage.

2 MODEL ESTABLISHMENT

2.1 Establishment of evaluation system model

Firstly, the goal of establishing the model is to evaluate the impact of different new technologies on automobile production efficiency, product quality, cost savings and market competitiveness, and then the corresponding hierarchical structure model is constructed.

Target layer (A): Evaluate the overall impact of different new technologies on the automobile manufacturing enterprise.

Criterion layer (C): automobile production efficiency (C1), vehicle production quality (C2), cost savings (C3), automobile market competitiveness (C4).

Solution layer (S): Artificial Intelligence (S1), Internet of Things (S2), Big Data Analytics (S3). The detailed hierarchical model is shown in Figure 1.

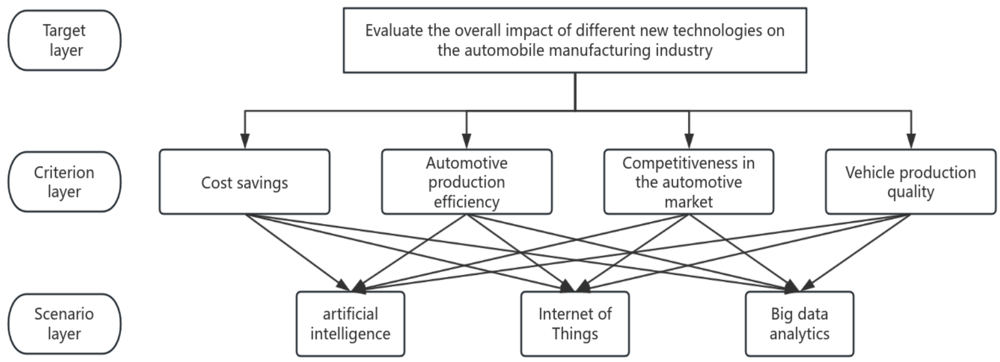


Fig. 1: Hierarchical model diagram

After constructing the hierarchy, the four factors of the criterion layer (automobile production efficiency (C1), vehicle production quality (C2), cost savings (C3), and LYNK&Co automobile market competitiveness (C4)) are compared in pairs, and then a complete judgment matrix is constructed by comparing the importance of the scheme layer under the criterion layer.

After completing the above process, the hierarchical general ranking is carried out, and the weights of each index are solved according to the judgment matrix we compose, and the square root method is used in this paper. For a given pairwise comparison matrix, the product of the elements in each row of the matrix is first calculated, as described in equation (1).

$$A = \prod_{j=1}^{m} a_{ij} \tag{1}$$

Where a_{ij} is the element of column j in row i, and for the product of each row, find its m root to obtain an m-dimensional vector.

$$\overline{W_i} = \sqrt[m]{\prod_{j=1}^{m} a_{ij}} \tag{2}$$

Where m is the number of rows (or columns) of the matrix. Normalizing the m power root value for each row (i.e., dividing each value by the sum of all values) gives the result of the weights of each factor:

$$W_i = \frac{\overline{W_i}}{\sum_{j=1}^{m} \overline{W_i}} \tag{3}$$

After obtaining the weights of each factor, the consistency test is carried out, and the maximum eigenroot is calculated first, as shown in equation (4).

$$\lambda_{max} = \frac{1}{n}\sum_{i=1}^{n} \frac{(AW)_i}{W_i} \tag{4}$$

Where n is the number of dimensions, and AW is the normalized weight of the judgment matrix. Next, the consistency indicator (CI) is calculated as follows:

$$CI = \frac{\lambda_{max} - n}{n - 1} \tag{5}$$

Here n is the number of the criterion, and λ_{max} is the maximum eigenroot. The stochastic consistency ratio (CR) is then solved, as shown in Equation (6).

$$CR = \frac{CI}{RI} \tag{6}$$

Among them, RI is a random consistency index, which can be determined according to the number of criteria. If the CR <0.1, the consistency of the judgment matrix is considered acceptable. Finally, combined with the weight of the criterion layer and the weight of the corresponding criterion at the scheme layer, the comprehensive weight of the scheme was calculated to carry out the total ranking of the levels. The process is carried out from the highest level to the lowest level, and then the consistency test is carried out based on the comprehensive weights, and then the comprehensive score (V_k) of the three schemes (Artificial Intelligence (S1), Internet of Things (S2), and Big Data Analytics (S3)) is evaluated, and the one with the highest score is the most advantageous technology choice.

2.2 New technology application and production process optimization plan

2.2.1 Technology selection and testing process

In this solution, intelligent robots and automated assembly line technologies are selected, as well as an AI-based logistics management system [5], and the specific test process is as follows:

The first step was to select a small-scale production link and a logistics center as the test site. Adopt new technologies, collect test data, analyze existing production lines and logistics chains, and identify inefficiencies. Then, the production line layout and logistics process that integrate automation technology are designed, and automation technology and AI logistics system are introduced to identify inefficient links. Employees are trained in the operation of automated equipment and the use of logistics systems prior to the trial to ensure that employees are able to operate the new technology. Based on the results of the pilot, the degree of automation and logistics strategy will be adjusted, and after confirming that the technology is effective, it will be expanded to all production lines and logistics centers.

Finally, by monitoring production and logistics data in real time, data-driven decision-making is used to continuously adjust and optimize processes.

This paper predicts that through the effective management of test sites in the early stage, the production efficiency of enterprises can be effectively improved, production time and manual errors can be reduced, costs can be reduced, and logistics speed and distribution efficiency can be improved. Of course, there will also be some challenges encountered during the experiment, such as the compatibility of new technologies with existing equipment and software, the lack of funds caused by the large initial investment of automation equipment and systems, etc., which will be effectively solved with the increasing improvement of the system and the continuous improvement of technology.

2.2.2 Establishment of efficiency improvement model

Considering both production and logistics, we can build several simple models to describe the efficiency gains after the introduction of new technologies. In this paper, the following models are used:

(1) Multi-link efficiency improvement model

It is assumed that the production process consists of N key links, and the efficiency improvement after the introduction of new technologies in each link can be described using a similar exponential growth model, but with different parameters to reflect the characteristics of different links. For the ith production link, the efficiency improvement model is as follows:

$$E_i(t) = E_{i0} + (E_{imax} - E_{i0}) \cdot (1 - e^{-\alpha_i t}) \quad (7)$$

Among them, the E_{i0} is the initial efficiency improvement of the ith link, the E_{imax} is the maximum efficiency improvement of the ith link, and the α_i is the efficiency improvement rate parameter of the ith link. The following is a model that can be applied to productivity improvement and logistics efficiency improvement. The productivity improvement model is as follows:

$$E_{prod}(t) = E_{0,prod} + \left(E_{max,prod} - E_{0,prod}\right) \cdot (1 - e^{-\alpha_{prod} \cdot t}) \quad (8)$$

The logistics efficiency improvement model is as follows:

$$E_{log}(t) = E_{0,log} + \left(E_{max,log} - E_{0,log}\right) \cdot (1 - e^{-\alpha_{log} \cdot t}) \quad (9)$$

Where t represents the time, $E_{0,prod}$ and $E_{0,log}$ represent the initial efficiency of production and logistics before the introduction of new technologies, $E_{max,prod}$ and $E_{max,log}$ represent the maximum efficiency improvement that can be achieved after the introduction of new technologies, and α_{prod} and α_{log} represent the rate parameters of efficiency improvement. By adjusting these parameters, it is possible to simulate the specific effects of different new technologies as they are introduced.

(2) Product quality improvement model

Firstly, the objectives and parameters of the model are determined, and the goal of the model in this paper is to shorten the production cycle, reduce labor costs, or improve logistics efficiency. The model parameters are production time, cost, product qualification rate, logistics time and logistics cost. The model architecture includes both production and logistics, in which intelligent robots and automated assembly lines are used in the production process, which can reduce manual operation errors and improve production speed and consistency, thereby improving product quality and production efficiency. Choosing automation technology (such as automated warehousing systems) in the logistics link can optimize inventory management, speed up the loading and unloading and transportation of goods, and reduce logistics delays and damages.

Once the model architecture is determined, collect data on existing production lines and logistics systems to capture data on the expected improvements with the introduction of intelligent robotics and automation technologies. Then, the collected data is used to build a preliminary model, run the model through simulation, observe how well the model output matches the actual or expected data, and adjust the model parameters accordingly to improve the accuracy and reliability of the model.

Analyze the model results to identify specific areas of improvement for intelligent robotics and automation technologies. Further optimize the model, such as adjusting the number of robots, changing the layout of the production process, adjusting the logistics strategy, etc., to achieve maximum efficiency improvement. Finally, the model is translated into specific operations and strategies, which are implemented in production and logistics. At the same time, the implementation effect is continuously monitored and feedback is collected to further refine and improve the model.

(3) Cost change model

The introduction of new technologies is usually accompanied by an increase in initial investment costs, but long-term operating costs may decrease due to efficiency gains. It can be described using a model that includes changes in initial investment and operating costs. Cost changes can be divided into initial investment costs C_{init} and operating costs over time $C_{op}(t)$, while operating costs $C_{op}(t)$ are:

$$C_{op}(t) = C_{base} - \sum_{i=1}^{n} \delta_i E_i(t) \tag{10}$$

Among them, the C_{base} is the basic operating cost, and the δ_i is the contribution coefficient of the efficiency improvement of the i th link to the cost savings.

2.3 Risk assessment models and risk management strategies

In view of the risk profile in the process of introducing new quality productivity, this paper will design a corresponding risk assessment model and risk management strategy [6]. The specific solution process is shown in Figure 2.

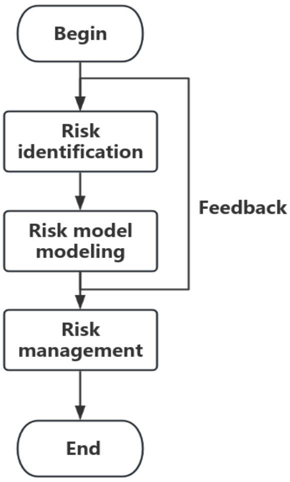


Fig. 2: Strategies to address risks

The risks that car companies may face mainly include technical risks, management risks, and market risks. As shown in Table 1, this paper will use a scoring system to score the risk probability and impact degree, and finally obtain the risk value, and then formulate the corresponding risk management strategy [7].

Table. 1: Table of risk possibilities

Types of Risks	Technical Risks	Management Risks	Market Risks
Possibility (p)	1 Mature technology and low risk.	1 Stable management and efficient team.	1 The market demand is stable and the forecast is accurate.
	2 There are technical challenges	2 There are challenges in business management, but there are countermeasures.	2 Market demand fluctuates, but is predictable.
	3 The technology is immature and there are significant risks.	3 Poor management of the enterprise and instability of the team.	3 The market demand is uncertain and difficult to predict.

Table. 2: Table of the degree of risk impact

Types of Risks	Technical Risks	Management Risks	Market Risks
Degree of impact (I)	Technical challenges have little impact on production.	Organizational hurdles have little impact on the enterprise.	Market changes have little impact on sales.
	Technical challenges can lead to production interruption or reduction of production efficiency	Administrative complexities can lead to waste of resources and damage to corporate image.	Market changes will lead to a decrease in sales.
	Technical constraints can lead to a complete shutdown of the production line.	Management difficulties can lead to chaos in business operations.	Market changes can cause sales to plummet.

Based on the above scoring scale of likelihood and degree of impact, we can calculate the priority of each risk, i.e., the risk value ($R = P * I$). We can formulate a risk management strategy based on the size of the value of risk [8].

There are three main ways to conduct risk assessment on the risks that car companies may face:

(1) Cost-benefit analysis

The total cost of introducing new technologies, including R&D costs, equipment investment, training expenses, etc. Expected annual earnings increases, including cost savings due to increased production efficiency and additional sales revenue from improved product quality. The cost-benefit ratio (CBR) is calculated by the following formula:

$$CBR = \frac{\sum_{t=1}^{n} \frac{B_t}{(1+r)^t}}{C_{total}} \tag{11}$$

Where C_{total} is all expected benefits due to the implementation of the project, B_t is the income in year t, r is the discount rate, and n is the number of years of the project life. If the CBR is less than or equal to 1, it means that for every unit of currency invested, at least one unit of currency can be benefited, which means that the project is considered economically viable. Conversely, if the CBR is greater than 1, then the cost of the project outweighs the benefits it brings and may not be an economically sound investment.

(2) Net present value

The net present value is equal to the total present value of future returns minus the present value of the initial investment, calculated as follows:

$$NPV = \sum_{t=1}^{n} \frac{B_t - C_t}{(1+r)^t} \tag{12}$$

Among them, B_t is the cost in year t, C_t is the amount of investment, r is the discount rate, and n is the number of years of project life.

(3) Internal rate of return

The internal rate of return is the discount rate at which the NPV equals zero and is often used to assess the profitability of a project. Calculating the IRR is complex and often requires the help of financial calculation software or iterative methods.

2.4 Technology refresh and business development planning

Considering the rapid development of new productivity technologies and the changes in the competitive environment of the industry, this paper uses the following model to develop a long-term technology renewal and business development plan for enterprises:

(1) Technology iteration model

This model selects technology maturity to describe the current technology level of the enterprise, which is calculated as follows:

$$T(t) = I(t)^{\alpha} \cdot \left(1 - e^{-\beta M(t)}\right) \tag{13}$$

Among them, $T(t)$ represents the technical maturity of time t, $I(t)$ represents R&D investment, α and β are adjustment parameters, and $M(t)$ represents market demand.

(2) Market expansion model

This model chooses the market expansion rate to describe the market share of the company, which is calculated as follows:

$$S(t) = \gamma \cdot T(t) - \delta \cdot C(t) \tag{14}$$

Where $S(t)$ represents the success rate of market expansion, γ and δ are the adjustment parameters, and $C(t)$ represents the expansion cost.

(3) Product innovation model

This model selects the success rate of product innovation to describe the product innovation ability of the enterprise, and the calculation formula is as follows:

$$P(t) = \gamma \cdot T(t) - \eta \cdot \frac{1}{F(t)} \tag{15}$$

Among them, $P(t)$ represents the success rate of product innovation, sum is the adjustment parameter, and (t) represents the frequency of product innovation.

3 MODEL SOLUTION

3.1 Hierarchical model solution results

In this paper, the established model and SPSS professional software are used to evaluate the impact of different new technologies on enterprise production efficiency, product quality, cost savings and market competitiveness, and the results are shown in Table 3~4.

Table. 3: Summary results of the judgment matrix

	Automobile Production Efficiency (C1)	Vehicle Production Quality (C2)	Cost Savings (C3)	Automotive Market Competitiveness (C4)	Eigenvectors	Weight Value (%)
Automobile Production Efficiency (C1)	1	0.333	0.5	5	0.955	19.724
Vehicle Production Quality (C2)	3	1	2	4	2.213	45.691
Cost Savings (C3)	2	0.5	1	3	1.316	27.168
AutomotiveMarket Competitiveness (C4)	0.2	0.25	0.333	1	0.359	7.417

Table. 4: Summary of the judgment matrix at the solution layer

Node Items	Artificial Intelligence	Big Data Analysis	Internet of Things	CR Value	Consistency Inspection
Automobile Production Efficiency (C1)	0.691	0.091	0.218	0.051	Pass
Vehicle Production Quality (C2)	0.54	0.163	0.297	0.009	Pass
Cost Savings (C3)	0.32	0.122	0.558	0.017	Pass

Automotive Market Competitiveness (C4)	0.136	0.625	0.238	0.017	Pass

The results show that the weight of automobile production efficiency (C1) is 19.724%, the weight of vehicle production quality (C2) is 45.691%, the weight of cost saving (C3) is 27.168%, and the weight of automobile market competitiveness (C4) is 7.417%. The maximum weight of the index is the production quality of the whole vehicle (C2) (45.691), and the minimum value is the competitiveness of the automobile market (C4) (7.417). The maximum feature root is 4.222, and the corresponding RI value is 0.882 according to the RI table, and the corresponding CR value is obtained according to equation (6), where the CR value is less than 0.1, so they all pass the one-time test.

The scores of the three scenarios are shown in Figure 3 below.

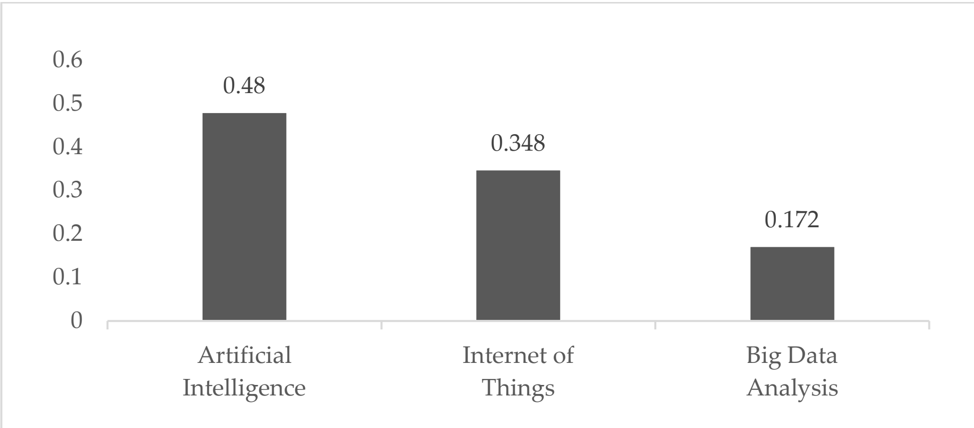
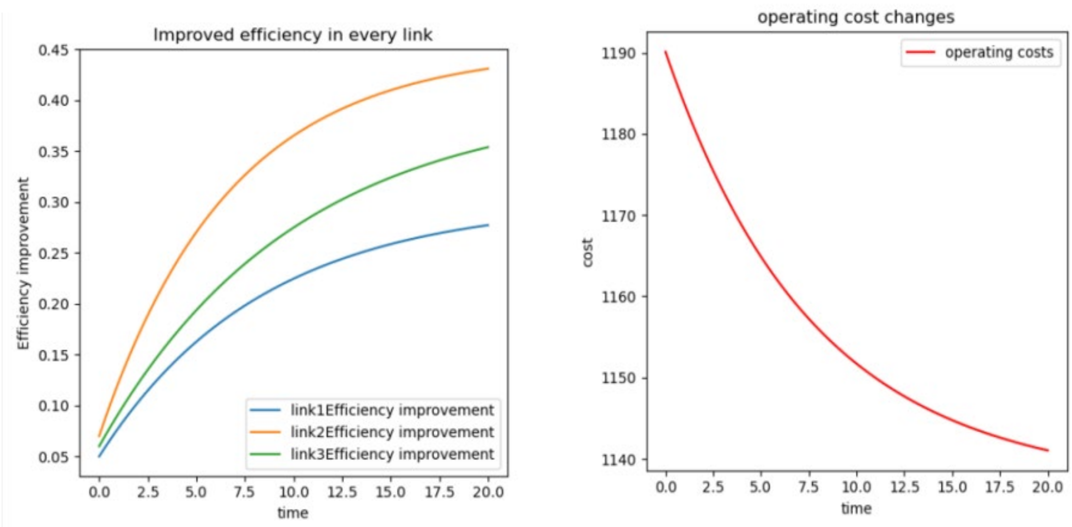


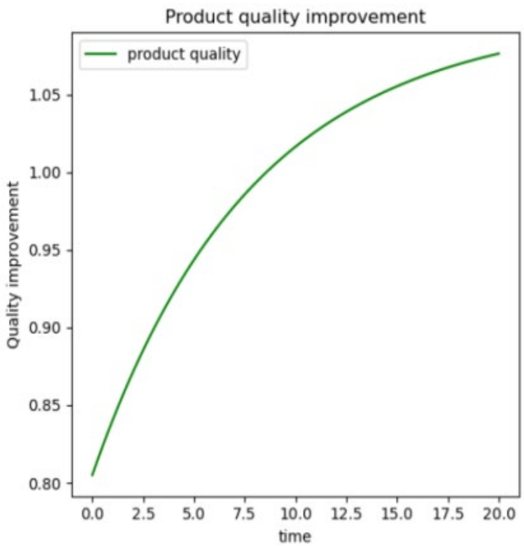
Fig. 3: Scheme score result

3.2 Efficiency improvement model solution results

According to the mathematical model established, the solution is solved, and then the corresponding code is written to output the result, and the solution result is shown in Figure 4.



(a) Improved efficiency in every link (b) Operating cost changes



(c) Product quality improvement

Fig. 4: Efficiency improvement model solution result diagram

Figure 4, from left to right, shows the simulation of efficiency improvement, operating cost changes, and product quality improvement in each link after the introduction of new technologies. As you can see from the graph, the efficiency of each production step gradually increases until it approaches its maximum efficiency improvement value. This shows that it may take time for a new technology to be fully effective in the initial stages, but it can significantly improve productivity in the long run. In addition, as efficiency increases, operating costs begin to fall. Initial costs may rise temporarily due to investment in new technologies, but overall costs tend to decline as efficiency gains and cost-saving measures are implemented. Product quality is gradually improving with the application of new technologies and the improvement of efficiency. This shows that new technologies can not only help improve production efficiency, but also improve product quality by improving production processes or introducing more advanced quality control techniques.

3.3 Risk assessment model solution results

According to the established risk model, here is an example to illustrate, assuming that we evaluate the introduction of autonomous driving technology by an automaker, the corresponding risk indicators and risk value scores are shown in Table 5 below.

Table. 5: Overall scores of car companies

Risk Types	Technical Risk	Management Risk	Market Risk
Probability Index	3	2	3
Impact Level Index	3	2	3
Risk Value	9	4	9

Based on the above scores, we can determine that technical risk and market risk are equally important and both need to be focused on. In response to these risks, measures can be taken, such as strengthening technology research and development, in-depth market research, and optimizing corporate management processes, to reduce risks and ensure the smooth implementation and sustainable development of the project.

In view of the risks that enterprises may encounter in the process of operation, this paper uses SWOT analysis to design risk management strategies, as shown in Table 6.

Table. 6: SWOT analysis table

Opportunities, threats / Advantages disadvantages	Chance(0) Meet the unexplored market demand Policy and regulatory support	Threaten(T) The intensification of market competition Uncertainty of regulations and policies
Advantage (s) It can significantly enhance the market appeal of products. Improve production efficiency and reduce costs. Environmentally friendly and sustainable development	SO strategy Increase the research and development and market application of new technologies. Expand the scale of the enterprise and add some equipment and machines.	ST strategy Improve production efficiency and reduce costs, and increase market share. Introduce new technicians to make breakthroughs in technology.
Disadvantage (w) Ang's initial investment Operation implementation and risk adaptation Uncertainty of field acceptance	WO strategy Improve the market acceptance of high-tech through marketing and brand cooperation. Increase subsidies for new technology employees.	WT strategy Strengthen market research and consumer trend analysis. Actively seek the support of the government and industry associations.

3.4 Long-term technology refresh resolution strategy

In this section, the model will be solved, and the results are shown in Figure 5.

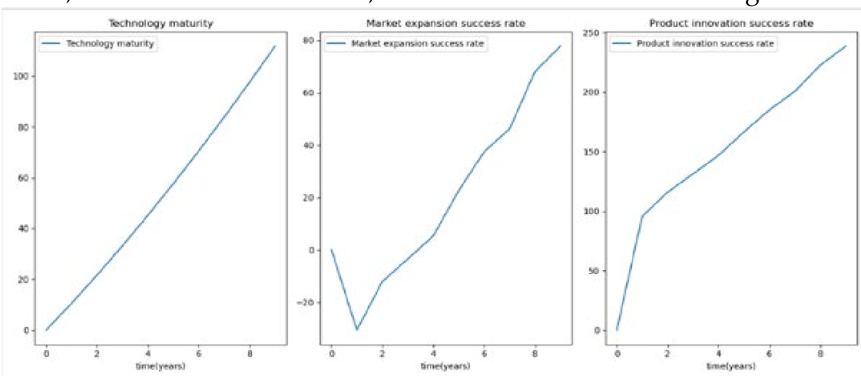


Fig. 5: Diagram of the model solution result

Among them, from left to right are the curves of technology maturity, market expansion rate and product innovation success rate.

The results show that in the technology iteration model, the technology maturity increases with the increase of time and R&D investment, and is also affected by market demand. In the market expansion model, the success rate is not only affected by the technical maturity, but also by the expansion cost and the market competition environment (simulated as random factors). In the product innovation model, the success rate is influenced by R&D investment, technology maturity and market expansion success rate. This model is highly simplified, and more factors may need to be considered in practical application, such as the specific situation of different market regions, the behavior of competitors, changes in economic environment and so on.

3.5 Enterprise Future Planning

When it comes to long-term technology updating and business development planning, enterprises need to consider many factors, including the rapid development of new quality productivity technology and changes in the competitive environment of the industry. Manufacturing enterprises should make specific plans for digital technology innovation, market expansion and product innovation.

Technical iteration is an important way for manufacturing enterprises to maintain their competitiveness. The rapid development and wide application of digital technology provide the core power for new quality productivity, so strengthening digital technology innovation is the key to form new quality productivity. Market expansion is an important way for manufacturing enterprises to increase their income. Including: emerging markets and future markets. Emerging industries have the characteristics of active innovation and technology-intensive, which provides a huge space for the development and growth of new quality productivity. Product innovation is an important way for manufacturing enterprises to meet customer needs. Manufacturing enterprises should focus on the development of new products and product upgrading. The development of new products needs to be evaluated based on market demand and technical feasibility. Manufacturing enterprises should pay attention to the changes of consumer demand and make use of the latest technology to carry out product innovation. Product upgrading is an important strategy for manufacturing enterprises to cope with market competition. Manufacturing enterprises should pay attention to the improvement of product performance and the expansion of product functions. Generally speaking, the long-term technical renewal and business development planning of manufacturing enterprises should comprehensively consider technical iteration, market expansion and product innovation, so as to ensure that they remain in the leading position in the fierce market competition.

4 CONCLUSIONS

Some methods adopted in this paper, such as AHP, can be used for reference in dealing with some optimization problems, which are suitable for variables controlled by many factors and have certain changing rules, and can be extended to the study of similar problems. In addition, it should be noted that the model still has some shortcomings. For example, AHP depends on the subjective judgment of decision makers to a certain extent, and different people's evaluations may lead to different results. The model is at risk of over-reliance on the results of the model, ignoring factors outside the model, such as human intuition, experience and changes in the external environment. Therefore, we still need to sum up experience, overcome shortcomings, and lead the research in depth.

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