Risk assessment of new quality productivity technology based on analytic hierarchy process and SWOT analysis

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ABSTRACT

With the continuous progress of technology, new production technologies such as artificial intelligence, big data analysis, and the Internet of Things have been widely applied in various industries, significantly improving production efficiency and product quality, and fundamentally changing traditional production and operation methods. A manufacturing enterprise needs to consider many issues when introducing new productivity technologies, such as cost, safety, and compliance. The risk assessment model using Analytic Hierarchy Process and SWOT analysis can help decision-makers conduct multi-objective screening to improve the efficiency and accuracy of strategy formulation.

When selecting new quality productivity technologies that are suitable for the existing production system of the enterprise, an evaluation system should be established, rather than blindly selecting the best performing technology from the public. For problem two, when integrating the selected artificial intelligence technologies into the current production system, the DMAIC method can be used in the design plan. For work three, after introducing new technologies, enterprises need to first use market experience to identify risks, then establish a risk matrix for visual display, and then use a risk assessment model based on SWOT analysis for comprehensive evaluation, and finally determine the corresponding risk management strategy.

Keywords: Entropy Weight Method, Analytic Hierarchy Process, Linear Programming, SWOT Analysis, S-Curve Model, Particle Swarm Optimization Algorithm

1 INTRODUCTION

With the rapid progress of technology, new generation production technologies such as artificial intelligence, big data analysis, and the Internet of Things are widely applied in the fields of production and services, greatly improving production efficiency and product quality, thereby changing traditional production and business methods. The current pursuit of high-quality development by enterprises requires new productivity theory guidance. New quality productivity has formed and demonstrated strong driving and supporting forces for high-quality development in practice. It is necessary to summarize and generalize its theory to guide new development practices [1]. As needed, research can be transformed into the following work for discussion.

When facing numerous innovative production technologies, enterprises need to clearly choose which technologies can bring the greatest benefits, and invest and apply them. Therefore, it is necessary to create an evaluation system and develop a set of evaluation criteria to evaluate the impact of different new technologies on the production efficiency, product quality, cost savings, and market competitiveness of enterprises [2]. Proposing a practical and feasible plan to organically integrate new technologies into existing production processes, including the actual application steps of the technology, expected benefits, and potential challenges. At the same time, develop a plan to improve the production process to fully tap into the potential of new technologies. When adopting new technologies, we often encounter various risks, such as technical difficulties, changes in market demand, and management difficulties. It is necessary to establish a comprehensive risk assessment structure and develop appropriate risk mitigation plans to address potential threats [3]. In the face of the development of new technologies and fierce market competition, enterprises need to formulate comprehensive long-term technological innovation and business growth strategic plans, covering various aspects such as technological upgrading, market expansion, and product innovation.

2 RELATED WORK

2.1 Work one

In various new productivity technologies, in order to find the most beneficial technology for enterprises and invest in its application, it is necessary to establish an evaluation system framework to screen. While considering key impact indicators, it is necessary to quantify these indicators and their proportion factors, then use the entropy weight method to obtain the weights of each factor, and finally establish a mathematical model to solve the problem.

The selection of the most favorable new productivity technology for investment and application is a multi-objective decision-making problem. It is necessary to consider how to balance the cost of new technology investment with the expected benefits, and determine the key indicators to measure the impact of new technology. Therefore, a set of evaluation system should be designed:

(1) Technical Feasibility Assessment: Technology Maturity (TM), Technology Adaptability (TA), Technology Integration Capability (TI)

(2) Production efficiency evaluation: degree of process optimization (PO), improvement in production speed (PS), and improvement in resource utilization (RU)

(3) Product Quality Assessment: Quality Stability Improvement (QS), Quality Indicator Improvement (QI), Customer Satisfaction Improvement (CS)

(4) Cost savings assessment: initial investment cost savings (IC), operating cost savings (OC), cost-effectiveness ratio (CB)

Collect sample data through an evaluation system, use entropy weight method to compare the weight of each indicator to the overall expected benefits, calculate the comprehensive evaluation total value, and then use Analytic Hierarchy Process to construct an evaluation model for comparing various indicators to obtain the optimal technology.

2.2 Work two

Firstly, convert the parameters of the current production system and new technologies into constraints and objective functions in mathematical models. Next, use a linear regression model to solve and determine the optimal technical application plan, which includes specific technical application steps, expected effects, and potential challenges. Using mathematical models and computer simulation tools to simulate the effects of integrating new technologies into existing production systems, including process simulation, queuing theory, and job research, to predict the impact of different integration schemes on production efficiency, cost, and output. Based on simulation results, develop a series of detailed technical application programs [4]. Utilize model results for production process optimization to maximize the advantages of new technologies.

2.3 Work three

It is necessary to establish a risk assessment model to identify and quantify potential risks encountered during the introduction of new technologies, and provide corresponding strategies for subsequent management. It is necessary to clarify what risks exist, which can come from various aspects and can be roughly divided into the following categories:

(1) Technical risk: Employees may experience technical errors or incompatibility with the existing system of the enterprise due to their lack of proficiency in operation;

(2) Market risk: refers to the possibility that new technologies may not be welcomed by the market or fail to meet market demand, resulting in product price fluctuations;

(3) Management risk: Introducing new technologies may bring management risks, including challenges in changing management methods, unclear internal responsibilities, poor communication, and low management efficiency;

(4) Economic risk: requires a large amount of upfront investment, but there may be uncertainty in investment returns and changes in cost structure.

After identifying potential risks, it is necessary to evaluate them. SWOT analysis can be used to assess risks and design corresponding strategies for risk control.

2.4 Work four

In order to cope with the rapid development of new generation productivity technologies and changes in the competitive environment in manufacturing enterprises, the primary task is to consider the technological development cycle, changes in market demand, and the direction of product innovation. Secondly, in response to the complexity of the problem, a framework programming dynamic model can be used to establish the model, and then simulation algorithms and optimization algorithms can be used to solve the model, such as using particle swarm optimization algorithm to find the best solution.

3 MODEL BUILDING AND ANALYZING

3.1 Model establishing and analyzing for work one

Firstly, it is necessary to determine the overall goals and objectives of the evaluation system. Based on the evaluation goals and needs, appropriate evaluation indicators should be determined, and the identified indicators should be organized into a system for a comprehensive evaluation of the evaluation object [5]. Choose appropriate evaluation methods, such as quantitative analysis, qualitative analysis, case studies, etc., and design evaluation methods to collect, analyze, and interpret evaluation data based on evaluation objectives and data sources.

The following are the steps to quantitatively represent and establish mathematical models for multi-dimensional indicators in various evaluation systems:

(1) Technical feasibility assessment, using values between 0 and 1 to represent the results of each indicator.

(2) Production efficiency evaluation, expressed as a percentage of the results.

(3) Product quality assessment, expressed as a percentage of the results.

(4) Finally, we can weighted the comprehensive scores of the five dimensions mentioned above to obtain the overall evaluation score for new technology investment and application.

According to the weight calculation of the Analytic Hierarchy Process, analyze the weights of various indicators and combine them with the consistency test results to determine whether there are logical problems in constructing the judgment matrix. By using the root square method to calculate the eigenvectors, the importance of the factors reflected in the eigenvectors can be obtained. Convert the feature vectors into weight values, which means that the feature variables are normalized and mapped to the 0-1 interval.

When constructing the judgment matrix, the consistency check result requires a CR value less than 0.1 to verify whether people's logic is correct. For example, when judging the importance of indicators A, B, and C, if A is more important than B and B is more important than C, then logically it should be A than C. If a judgment is constructed that A is more important than C but instead considers C to be more important than A, it will lead to logical errors and fail the consistency check [6].

The usual Analytic Hierarchy Process divides goals, factors, and the interrelationships between objects into the highest, middle, and lowest levels, and draws a hierarchical structure diagram. The system displays the goals pursued by the decision, the factors to be considered (i.e. decision-making principles), and the weight values corresponding to different factors.

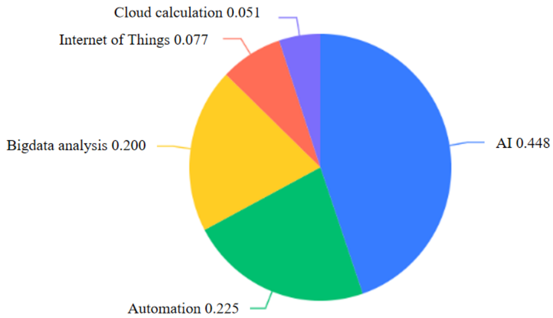

Fig 1: Score of New Quality Productivity

The above figure shows the weights of calculating the relative importance of all factors at a certain level to the highest level (overall goal). This process is usually completed in the last step of the calculation process, but for the convenience of viewing the quantitative results, it is now presented in advance.

We constructed a judgment matrix for leaf node indicators using the Analytic Hierarchy Process and analyzed the weights of each indicator. By displaying the consistency test results, it can be determined whether there is a logical problem in constructing the judgment matrix for the weight matrix of the scheme layer [7].

Due to the fact that the score of the higher-level node can be calculated based on its child node score * weight, when constructing the judgment matrix at the scheme layer, only the leaf nodes need to be constructed, that is, N leaf nodes correspond to N judgment matrices. This can be achieved by combining pairwise comparisons of different nodes to obtain the score of the solution layer for a leaf node, as the score of the higher-level node can be calculated based on the scores and weights of its child nodes.

From the above steps, it can be concluded that based on the single ranking of indicator levels and the overall ranking of scheme levels, artificial intelligence is the best solution for selecting the most advantageous technology for the enterprise, with a quantitative score of 0.448.

3.2 Model establishing and analyzing for work two

The optimal new productivity technology selected for problem one is artificial intelligence. The proportion of artificial intelligence usage in the manufacturing market has steadily increased after entering the market, which means that manufacturing companies are facing the challenge of integrating artificial intelligence into their production systems.

Adopting DMAIC (Definition, Measurement, Analysis, Improvement, Control) methods to effectively integrate artificial intelligence into the production system. DMAIC (Definition, Measurement, Analysis, Improvement, Control), as a representative of Six Sigma improvement methods, is widely used in the continuous optimization process of enterprises [8]. DMAIC is a method for improving production processes to optimize artificial intelligence production processes. The following are the DMAIC steps for integrating artificial intelligence technology into the production process:

Firstly, examine the bottlenecks and obstacles in the current production system, and clarify the key issues and requirements that can be solved through artificial intelligence technology. These issues may lead to reduced production efficiency, increased resource waste, and extended downtime of production lines.

If a manufacturing company has some important goals and key indicators in the production process, such as reducing production time, improving production efficiency, reducing costs, and optimizing resource utilization. Set clear improvement goals, such as increasing production capacity by 30% and reducing production costs by 15%.

For the production process, it is necessary to collect relevant data, including the operation of the production line, equipment failure information, and product quality data, and then process these data, including cleaning, organizing, and standardizing. Based on the collected data and target requirements, determine the current mean, standard deviation, or other important indicators as a reference before improvement [9]. After considering the resource and time constraints of the production line, establish a suitable planning model.

Using data analysis tools for statistical analysis, identify the main factors that affect production efficiency, and set the following relevant factors.

The impact of artificial intelligence on output is

$$\mathrm{B}_{\mathrm{i}'} = \mathrm{B}_{\mathrm{i}} \cdot (1 + \Delta \mathrm{E}_{\mathrm{i}}) \quad (1)$$

The impact of artificial intelligence on costs is

$$C_{i'} = C_1 \cdot (1 + \Delta C_i) \quad (2)$$

The impact of artificial intelligence on time is

$$D_i = D_i \cdot (1 + \Delta D_i) \quad (3)$$

Identify potential risk variables, such as equipment failure probability and efficiency loss: For all continuous production processes i and i-1, there are

$$B_{i'} = A_{i-1} \quad (4)$$

The probability of failure in production process i is $P_{fail,i}$;

The overall cost of equipment failure is S_{fail};

The overall efficiency loss due to equipment failure is E_{fail}.

Design experiment: Conduct a control experiment by organizing data to compare the output of artificial intelligence with traditional output.

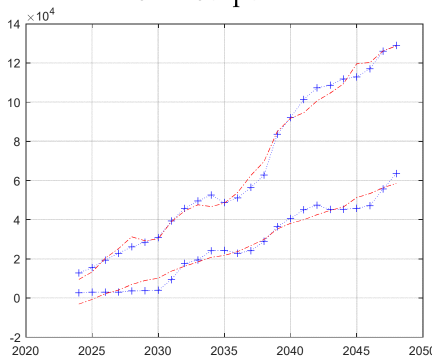

Fig.2: Comparison of output value-added from 2024 to 2048

Design a regression prediction model based on factors such as production output, input, cost, and efficiency, and design a simulated output value-added for 24 years starting from 2024, including potential challenges such as faults.

Use the constructed linear programming model to analyze and optimize production data. Using mathematical models for calculations to find the optimal production plan, thereby improving production efficiency and achieving other goals [10].

Based on the analysis results, propose targeted improvement measures, such as continuing to optimize algorithms, upgrading equipment, and improving maintenance plans.

3.3 Model establishing and analyzing for work three

Risk matrix is a tool commonly used in risk management and decision-making processes, which quantitatively evaluates potential risks by comprehensively considering the likelihood and impact of risk occurrence.

Firstly, when introducing new technologies, enterprises need to consider potential risks including market, management, economics, compliance, and security challenges. The risk probability levels correspond to 0.15, 0.3, and 0.55, respectively. The three risk impact levels correspond to 1000, 2500, and 5000, respectively.

Based on market research data, we have set a risk tolerance of 2500. We need to determine which risks exceed the risk tolerance, and then adjust the factors to lower the risks that exceed the risk tolerance. By calculation, the unadjusted comprehensive risk value is 3020, and the adjusted comprehensive risk value is 1178.75. It is necessary to remedy the risks that enterprises will face through risk management strategies based on data simulation calculations.

With the help of SWOT analysis, we can have a more comprehensive understanding of the risks faced by artificial intelligence in the production system of enterprises, explore possible future development trends and impacts, and formulate more appropriate strategic planning and risk management measures to ensure the correct application and healthy development of AI technology. Based on the risk matrix and SWOT analysis, we can prioritize risks as follows: economic risk ranks first, market risk and security risk rank second, followed by compliance risk and management risk.

The rapid development and widespread application of AI technology have brought enormous potential and change, but also a series of risks and challenges. In order to effectively manage these risks and ensure the successful introduction and safe use of AI technology, enterprises have adopted a series of strategies as follows:

Develop a comprehensive AI governance framework

(1) Policies and processes: Develop clear policies and processes to guide the development, deployment, and use of AI, with policies fully open to ensure transparency and subsequent traceability.

(2) Accountability mechanism: The management of the enterprise determines responsibilities and accountability mechanisms to ensure that a series of operations of the AI system comply with regulations.

Regularly evaluate changes in risk probability and risk impact to ensure the effectiveness of risk management strategies.

Ensure the credibility of the AI system

(1) Validity evaluation: Regularly evaluate the performance and credibility of AI systems, including accuracy, reliability, safety, and interpretability.

(2) Continuous improvement: Based on the performance evaluation results, continuously improve the design and practice of AI systems to enhance their quality and performance.

Implement risk and impact management

(1) Monitoring and recording: Real time recording and monitoring of AI system decisions and behaviors for subsequent accountability and correction of issues.

(2) Third party management: Using third-party software, data, and supply chain tactics for effective risk management, ensuring the credibility and security of the entire cycle system.

Encourage public participation and ensure transparency

(1) Communicating with the public: reaching a united front with the public, communicating the purpose, functionality, and potential risks of AI systems, thereby enhancing public trust and acceptance;

(2) Transparency: Disclose the working principle and decision-making process of AI technology, allowing for external review and evaluation.

Respect laws, regulations, and ethical standards

(1) Compliance: Ensure that the development and use of AI technology comply with relevant laws, regulations, and industry standards.

(2) Ethical Review: Regularly conduct ethical reviews of AI systems to ensure they comply with socialist core values.

7. Establish emergency response and recovery mechanisms

(1) Emergency plan: Develop an emergency plan to deal with errors or security incidents in AI systems.

(2) Recovery mechanism: Establish a rapid and effective functional recovery mechanism.

Through the above strategies, enterprises can better introduce and avoid AI technology, reduce the risks generated during the use process, and ensure that AI technology will have a positive effect on the development of enterprises in the future.3.4 Model establishing and solving for work four.

3.4.1 Technology update planning

Actively invest in artificial intelligence technology and automation equipment to improve production efficiency and quality control level. For example, using machine vision to improve the accuracy of product inspection and using robot automation to optimize production lines. Build an intelligent manufacturing system based on data and artificial intelligence to achieve intelligent optimization and resource allocation of the production process, improve production flexibility and response speed. Using digital twin technology to simulate the production process, product design, production process optimization, and fault prediction can reduce actual testing costs and shorten product launch time.

The technology S-curve model is a model used to describe the relationship between performance growth and investment in the process of technological development. In the early stages of technology, performance improvement was slow; With the maturity of technology, performance grows rapidly; When technology approaches its physical or theoretical limits, performance growth slows down. This relationship presents an S-shaped curve on the graph. In MATLAB, the logistic growth model can be used to fit and predict the S-curve of the development of artificial intelligence technology.

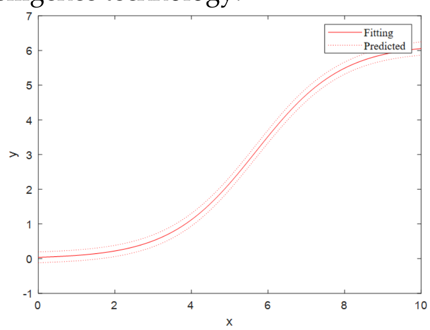

Fig.3: S-curve for predicting the maturity of artificial intelligence technology

3.4.2 Artificial intelligence technology iteration

The iteration of artificial intelligence technology refers to continuously improving its performance and efficiency by optimizing and updating it. With the continuous progress and in-depth research of technology, artificial intelligence technology is rapidly developing and evolving. Particle Swarm Optimization (PSO) is a commonly used heuristic optimization algorithm that plays an important role in the iterative process of artificial intelligence technology. The basic steps of implementing a particle swarm algorithm using MATLAB include initializing the particle swarm, determining the fitness function and objective, updating the velocity and position of particles, and updating the global optimal solution. The following are the specific steps to implement the particle swarm algorithm using MATLAB (assuming dimension D=1):

First, initialize the particle swarm. In a $D = 1$ dimensional space, there are N initialized particles with the following properties:

The position of the ith particle: xi

The velocity of the ith particle: vi

The best position passed by the ith particle: pbest;

The best position that the entire particle swarm passes through: gbest

Place restrictions on the positions of all particles: $x\lim_{x\to\infty} t_i \in [X_{\min}, X_{\max}]$

Limit the speed of all particles: $vlimt_i \in [V_{min}, V_{max}]$

Set the number of iterations: *inter*

Set the self-learning factor C1 of the particles during each iteration process. It is used to adjust the size of the self influencing factor on the step size of each particle movement.

Set the group learning factor C2 for particles during each iteration process. It is used to adjust the size of the influence factor of the "population" on the step size of each particle movement. During each iteration, the inertia weight of the particles is w. It is a non negative number used to reflect the ability to inherit one's own speed from the previous moment.

Finally, set the termination condition:

(1) Reached the set number of iterations.

(2) The difference between a certain indicator and the ideal target satisfies a certain minimum threshold. If the termination condition is not met, proceed to the second step.

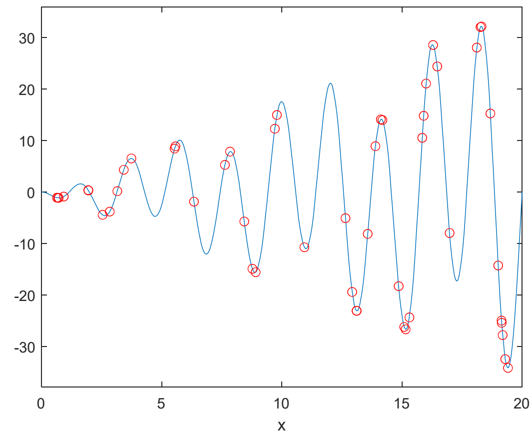

Fig.4: Initial state diagram

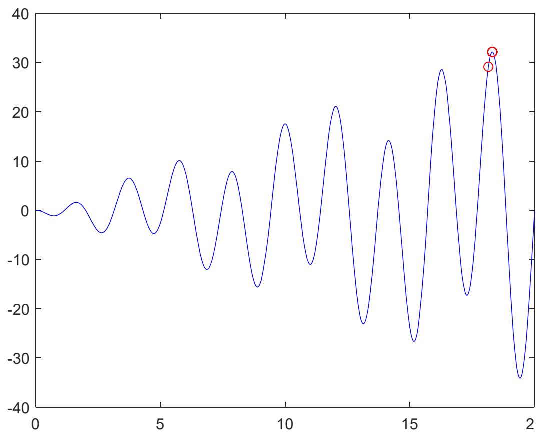

Fig.5: Status position change diagram

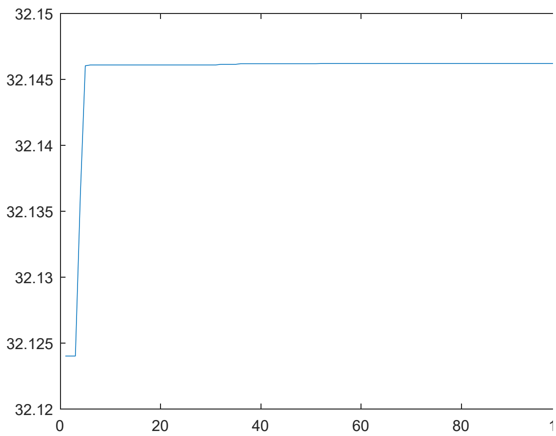

Fig.6: Convergence process

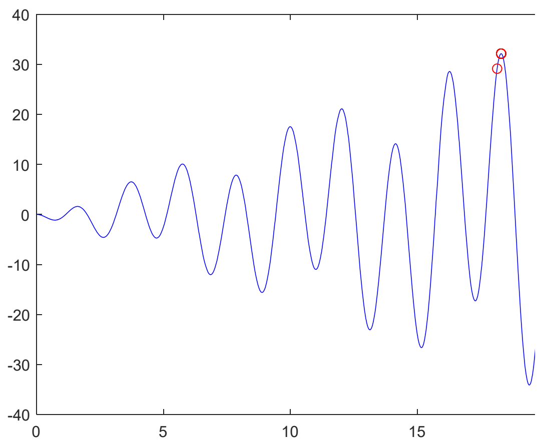

Fig.7: Final state diagram

Based on the above model, the conclusion is as follows:

(1) Maximum value: 32.1462;

(2) Variable value: 18.3014.

3.4.3 Market expansion planning and product innovation planning

Conduct in-depth research on the target market, accurately position the enterprise in the market, and develop specific marketing strategies for each segmented market. When considering expanding the international market of a company, one can choose to increase its global influence by exporting products or setting up branches in key markets. Utilize digital marketing tools such as social media and search engine optimization to enhance brand awareness and market share, and strengthen brand building. Pay close attention to changes in the market and user needs, regularly collect user feedback, and focus on user oriented product innovation. Develop green materials and design corresponding processes to produce low-carbon and recyclable products to meet the market demand for sustainable development products. By utilizing artificial intelligence and big data analysis technology, we provide consumers with personalized customization services to meet their personalized product needs.

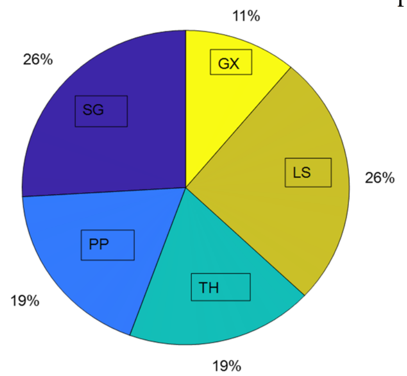

Fig.8: Porter's Five Forces Model Factor Ratio

The Porter's Five Forces model focuses on analyzing the competitive environment and cannot directly apply numerical calculations to determine results. Therefore, using the Porter's Five Forces model to study the competitive environment of the industry, in order to determine the direction of market and product expansion.

Set five parameters: SC: Market segmentation and positioning; PP: Brand building and marketing; YH: User demand orientation; LS: Green and sustainable production; GX: Personalized customization service.

Each parameter has a rating of 1-10, and according to the rating of a listed manufacturing enterprise, SG=7, PP=5, YH=5, LS=7, GX=3. It can be concluded that the total score is 27, indicating a lower level of industry competition and higher attractiveness.

The long-term technological updates and business development plans of manufacturing enterprises should be a dynamic adjustment process, requiring enterprises to continuously learn the latest technological development trends, understand changes in market demand, and adjust their strategic direction based on these changes. Through continuous technological innovation, market expansion, and product innovation, manufacturing enterprises can maintain a leading position in future competition.

4 CONCLUSION

Connecting anything in an ideal nonlinear continuous world to simulate the effects of most phenomena in the physical world, and achieving the goal of mean prediction. In terms of online correlation detection algorithms, they can be applied to evaluate changes in the performance of different devices, so that operators can adjust and update in a timely manner, and prevent accidents from occurring. In the field of environmental protection, prediction algorithms based on linear correlation can be applied to monitor changes in the concentration of inhalable particles in the atmosphere, to assist relevant departments in analyzing social phenomena and improving the quality of living environment. The entropy weight method and TOPSIS method are similar in that they are objective weighting methods that determine weights based on the degree of variation of indicators. The smaller the degree of variation of the indicator, the less information it reflects, so the corresponding weight should also be lower. Note: Purpose=The data itself can tell the weight. The entropy weight method requires sufficient data support when dealing with practical problems in enterprises. Although the method is simple, it is very practical and can be used to preliminarily determine weights, and then combined with other methods for optimization.

The risk matrix is a tool used by enterprises to determine risk priorities, evaluating the probability of risk occurrence and the severity of its impact. By presenting risks through charts, it is possible to more intuitively identify and prioritize risks. To assist decision-makers in rational resource allocation and planning, provide a clear structure to consider the likelihood and impact of risks. Helping stakeholders communicate risk information, suitable for organizations of various sizes and types, as well as different industries and fields. It can be applied in various industries. The creation and use of matrices are easily influenced by subjective factors, which may reduce accuracy and reliability. Sometimes oversimplifying the actual situation. Static graphics cannot capture the dynamic characteristics of risk over time. Unable to provide an opinion on the overall risk situation

5 ACKNOWLEDGEMENTS

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