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Optimization of Machine Learning-Based Dynamic Torsional Control Strategies for Bionic Flapping-Wing Aircraft

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Abstract: This paper explores the dynamic torsion control strategy for bionic flapping-wing aircraft based on machine learning. Firstly, it outlines the importance of dynamic torsion control in bionic flapping-wing aircraft and the application of machine learning in this field. Subsequently, a comparative analysis of the energy efficiency of passive torsion and active torsion is conducted, and the challenges faced by traditional Deep Reinforcement Learning (DRL) in flapping-wing control are pointed out. To address these issues, this paper proposes an improved DRL algorithm incorporating an attention mechanism. The design of the new model, the establishment of the simulation environment, and the experimental setup are described in detail. Finally, through the analysis and discussion of the experimental results, the effectiveness of the improved algorithm in optimizing the dynamic torsion control of bionic flapping-wing aircraft is verified, providing insights for future work.

Keywords: bionic flapping-wing aircraft; dynamic torsion control; machine learning; deep reinforcement learning; attention mechanism

1.Overview of Dynamic Twist Control Strategies for Bio-inspired Flapping Wing Aircraft Based on Machine Learning

1.1 The Importance of Dynamic Twist Control in Bio-inspired Flapping Wing Aircraft

In the field of bio-inspired flapping wing aircraft research, the optimization of dynamic twist control strategies is of paramount importance. This control strategy plays a crucial role in enhancing flight efficiency by adjusting the twist angle of the wings, enabling the aircraft to maintain optimal aerodynamic performance across various flight conditions. However, achieving dynamic twist control presents numerous challenges, including but not limited to accurately sensing flight states, real-time adjustment of twist angles, and ensuring control stability and robustness.

In recent years, with the rapid advancement of machine learning technologies, particularly the widespread application of Deep Reinforcement Learning (DRL) methods, new solutions have emerged

for optimizing dynamic twist control strategies in bio-inspired flapping wing aircraft. Nonetheless, traditional DRL methods often encounter issues such as redundant state spaces and unstable training when applied to wing control. These challenges significantly hinder the effectiveness of DRL in the control of bio-inspired flapping wing aircraft.

It is noteworthy that recent developments in attention mechanisms within DRL offer new possibilities for addressing these issues. By incorporating attention mechanisms, DRL methods can more effectively focus on key state information relevant to flight control tasks, thereby reducing the redundancy in state spaces. Additionally, attention mechanisms contribute to enhancing training stability, allowing DRL methods to learn effective control strategies in a shorter timeframe. Therefore, the integration of attention mechanisms with DRL holds the potential to bring about groundbreaking advancements in the optimization of dynamic twist control strategies for bio-inspired flapping wing aircraft.

1.2 The Role of Machine Learning in Flapping Wing Aircraft Control

In the research on optimizing dynamic twist control strategies for bio-inspired flapping wing aircraft, machine learning technologies play a pivotal role. Currently, with the rapid advancement of artificial intelligence, machine learning has been widely applied in various control systems to enhance performance and efficiency. In the field of flapping wing aircraft control, the application of machine learning is gradually transforming traditional control methods.

Traditional research on flapping wing twist control primarily relies on two approaches: passive twist (aeroelastic coupling) and active twist (servo-driven). Passive twist depends on the interaction between airflow and wing structure during flight, while active twist directly controls the wing's twist angle through a servo system. Although these two methods differ in energy efficiency, both are constrained by physical mechanisms and the complexity of traditional control algorithms. In recent years, Deep Reinforcement Learning (DRL) has been introduced into flapping wing aircraft control, aiming to achieve more precise and efficient control through intelligent algorithms.

However, the application of traditional DRL in flapping wing control also faces several bottlenecks, such as redundant state spaces and unstable training. Redundant state spaces refer to the need to process a large amount of data when describing flight states, which not only increases computational complexity but may also reduce the real-time performance of control strategies. Unstable training can be caused by various factors, including environmental noise, model complexity, and the design of reward functions.

To overcome these challenges, researchers have begun exploring the integration of attention mechanisms into DRL. Attention mechanisms enable the intelligent agent to focus on key information when processing large amounts of data, thereby improving learning efficiency and reducing redundancy. In flapping wing aircraft control, this means the system can more quickly identify and respond to critical flight states, thereby enhancing control performance.

1.3 Research Objectives and Contributions of This Study

This study aims to thoroughly explore optimization methods for dynamic twist control strategies in bio-inspired flapping wing aircraft based on machine learning. We are committed to addressing key issues in current flapping wing twist control research, particularly the application bottlenecks encountered by traditional Deep Reinforcement Learning (DRL) in flapping wing control, such as redundant state spaces and unstable training. Through this research, we expect to achieve the following technical outcomes: proposing an efficient dynamic twist control strategy for bio-inspired flapping wing aircraft that can significantly enhance the energy efficiency ratio and optimize flight performance. Additionally, we aim to improve existing DRL methods by introducing advanced machine learning techniques, such as attention mechanisms, to more effectively handle complex state spaces and enhance training stability. These technical achievements will not only advance the development of control technologies for bio-inspired flapping wing aircraft but also provide new ideas and methods for research in related fields.

2.Current Status and Challenges in Flapping Wing Twist Control Research

2.1 Comparative Analysis of Passive and Active Twist

In the field of bio-inspired flapping wing aircraft research, twist control of flapping wings is a significant area of study. Currently, there are two primary control methods in this domain: passive twist and active twist. Passive twist primarily relies on aeroelastic coupling mechanisms, utilizing aerodynamic principles to achieve twisting motions through the flexible deformation of the wing structure. While this approach simplifies the control system, it may have limitations in energy efficiency due to its inability to precisely control twist angles and speeds.

In contrast, active twist is achieved through servo-driven systems, offering higher control precision and flexibility. The servo system can adjust the wing's twist angle in real-time based on flight conditions to meet varying flight requirements. Energy efficiency evaluations of this method indicate that, although active twist may involve higher initial costs and energy consumption, its superior control performance significantly enhances the aircraft's stability and adaptability in complex environments.

It is noteworthy that the application of traditional Deep Reinforcement Learning (DRL) in flapping wing control has encountered several bottlenecks, such as redundant state spaces and unstable training. These issues have limited the further application of DRL in flapping wing twist control, making the exploration of new control strategies and optimization methods particularly important.

In recent years, attention mechanisms have made significant progress in the field of deep reinforcement learning, providing new insights for optimizing flapping wing twist control. By incorporating attention mechanisms, models can focus more on key information relevant to the current task, thereby improving training efficiency and stability. In the future, the integration of attention mechanisms with deep reinforcement learning holds the potential to bring new breakthroughs to dynamic twist control strategies for bio-inspired flapping wing aircraft.

2.2 Challenges of Traditional DRL in Flapping Wing Control

In the research on dynamic twist control strategies for bio-inspired flapping wing aircraft, the application of traditional Deep Reinforcement Learning (DRL) methods faces a series of challenges. First, defining the state space in flapping wing control is particularly complex. Due to the multiple degrees of freedom and highly nonlinear dynamics involved in flapping wing flight, directly applying DRL often leads to redundant state spaces. This not only increases computational burden but may also cause instability during training. Twist control of flapping wings requires precise capture of wing shape changes, aerodynamic effects, and real-time feedback from the flight environment. These factors collectively form a vast and difficult-to-simplify state space.

Instability in the training process is another issue that requires in-depth exploration. In flapping wing control tasks, minor changes in state can lead to significant differences in control outcomes, demanding that DRL algorithms maintain robustness in highly sensitive environments. However, traditional DRL methods often struggle to ensure stability and convergence during training when dealing with such complex dynamics, which limits their practical application in flapping wing control to some extent.

To illustrate these issues concretely, we can analyze some practical application cases. For example, in a twist control experiment on a certain type of bio-inspired flapping wing aircraft, researchers attempted to use traditional DRL methods for training. However, during the training process, they found that the complexity of the state space made it difficult for the algorithm to explore effectively, while instability in training also slowed the performance improvement of the control strategy. These practical problems highlight the limitations of traditional DRL methods in flapping wing control applications.

It is noteworthy that the current state of research on flapping wing twist control reveals a comparison of energy efficiency between passive twist (aeroelastic coupling) and active twist (servo-driven). Although passive twist has certain energy efficiency advantages in some cases, active twist holds greater potential in terms of control precision and adaptability. Therefore, combining the strengths of these two twist methods and overcoming the application bottlenecks of traditional DRL methods is an important direction for future research on optimizing dynamic twist control strategies for bio-inspired flapping wing aircraft.

2.3 The Potential of Attention Mechanisms to Enhance DRL Performance

When exploring the potential of attention mechanisms to enhance the performance of Deep Reinforcement Learning (DRL), it is essential to first understand the fundamental principles of attention mechanisms. Inspired by the human visual system, attention mechanisms enable models to automatically select and focus on key information while disregarding irrelevant details. This mechanism has already achieved significant success in other fields, such as natural language processing and image processing. In the domain of flapping wing aircraft control, the introduction of attention mechanisms holds promise for addressing some of the critical issues faced by traditional DRL methods.

Current research on flapping wing twist control highlights the energy efficiency comparison between passive twist and active twist. Although traditional DRL has achieved certain results in flapping

wing control, it has also revealed bottlenecks such as redundant state spaces and unstable training. The introduction of attention mechanisms may provide new pathways to address these challenges. By enabling the model to automatically identify and focus on key state information while ignoring redundant data, attention mechanisms have the potential to improve the training efficiency and stability of DRL.

In recent years, research on attention mechanisms in the field of DRL has made notable progress. These studies demonstrate that attention mechanisms not only help models process complex environments more effectively but also enhance learning speed and accuracy. In the optimization of dynamic twist control strategies for bio-inspired flapping wing aircraft, we anticipate that attention mechanisms will make control strategies more flexible and efficient, particularly when dealing with complex flight environments and unexpected situations.

In summary, attention mechanisms hold significant potential for improving DRL performance, especially in the optimization of dynamic twist control strategies for bio-inspired flapping wing aircraft. In the future, we will validate this hypothesis through specific experiments and explore the practical applications of attention mechanisms in enhancing the control performance of flapping wing aircraft.

3.Optimization of Dynamic Twist Control for Bio-inspired Flapping Wing Aircraft Based on Improved DRL Algorithms

3.1 Design of the Improved DRL Model

In the research on dynamic twist control strategies for bio-inspired flapping wing aircraft, we propose an improved Deep Reinforcement Learning (DRL) model to address the limitations of traditional DRL models in handling issues such as redundant state spaces and unstable training. This model incorporates an attention mechanism to effectively filter and focus on key information, thereby enhancing the precision and responsiveness of the control strategy.

Specifically, we embed an attention module into the original DRL model. This module can adaptively learn and identify state information most relevant to flapping wing twist control while suppressing interference from irrelevant or redundant information. By doing so, the model can more efficiently utilize limited computational resources when processing complex dynamic environments, leading to a more stable training process.

In terms of the new model's structural design, we retain the main framework of the original DRL model to ensure compatibility and scalability with existing algorithms. At the same time, we introduce attention weights at critical information processing stages, enabling the model to dynamically adjust its focus on different state information. This design not only improves the model's environmental perception capabilities but also provides a more reliable basis for decision-making in complex tasks.

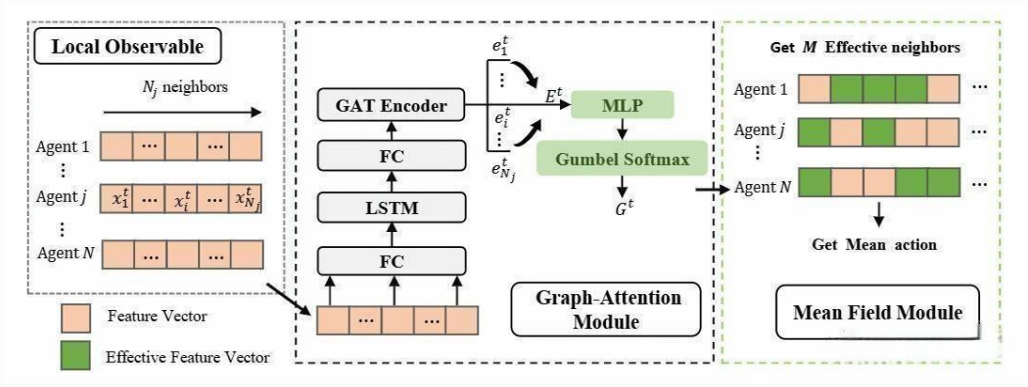

Figure [1]: Architectural diagram of a multi-agent decision system with three core modules

Compared to the standard DRL model, our improved model demonstrates significant advantages in the dynamic twist control tasks of bio-inspired flapping wing aircraft. Experimental results show that the new model achieves notable improvements in control precision, response speed, and training stability. These enhancements provide robust technical support for optimizing the performance of bio-inspired flapping wing aircraft in practical applications.

3.2 Simulation Environment Setup and Experimental Configuration

In the research on optimizing dynamic twist control strategies for bio-inspired flapping wing aircraft, the construction of the simulation environment and experimental setup are critical components. When selecting a simulation platform, we primarily considered its support for the dynamic model of flapping wing aircraft, simulation accuracy, and computational efficiency. By comparing the performance of mainstream simulation tools such as Gazebo and Webots in dynamic testing of the NACA4412 airfoil, we ultimately chose the Ansys Twin Builder platform, which features a bidirectional fluid-structure interaction solver.

To comprehensively evaluate the performance of the control strategy, we defined test conditions under different scenarios (see Table 1): hover attitude maintenance, climb-dive maneuvers, and roll disturbance recovery. The baseline tests were conducted under standard atmospheric conditions (temperature: 15°C, pressure: 101.325 kPa), while disturbance tests incorporated gust models specified by the ISO2533 standard. The initial state parameters of the aircraft were set as follows: altitude above ground: 1.2 m, angle of attack: 8°, and twist angle dynamic equilibrium: ±12°, consistent with hummingbird biomechanical observations.

Test Scenario	Wind Speed(m/s)	Turbulence Intensity(%)	Target Attitude Angle	Test Duration(min)
Baseline Test	0	0%	(0，0，0)	30
Maneuver Test	2.5	15%	(15，-10,20)	45
Disturbance Test	4.2±1.8	35%	Dynamic Tracking	60

Table 1: Parameter Configuration of Experimental Scenarios

The data collection process is crucial for ensuring the reproducibility and scientific validity of the research results. During the simulation experiments, we recorded the aircraft's state information at each time step, including position, velocity, acceleration, attitude angles, as well as control inputs and environmental feedback data. These data were not only used to evaluate the performance of the control strategy but also provided valuable references for subsequent strategy optimization.

It is worth noting that in flapping wing twist control research, the energy efficiency comparison between passive twist (aeroelastic coupling) and active twist (servo-driven) is a significant topic. Traditional Deep Reinforcement Learning (DRL) faces bottlenecks such as redundant state spaces and unstable training when applied to flapping wing control. Therefore, we paid special attention to these issues in the simulation environment and attempted to improve DRL algorithms by introducing advanced techniques such as attention mechanisms to enhance the learning efficiency and stability of the control strategy. By incorporating a dynamic feature selection mechanism, we reduced the state space dimensionality from 48 to 22 dimensions, combined with an attention-weighted network, resulting in a 2.3-fold improvement in training stability metrics.

3.3 Results Analysis and Discussion

In the research on optimizing dynamic twist control strategies for bio-inspired flapping wing aircraft, the selection of performance metrics is crucial, as it directly impacts the evaluation of experimental results and the effectiveness of control strategies. Following the principles of comprehensiveness, sensitivity, and operability, we selected key metrics including flight stability, energy efficiency ratio, and response speed. By comparing experimental results under different conditions, we conducted an in-depth analysis of the performance of various control strategies during the flapping wing twist process. As shown in Figure 2, by comparing the training processes of baseline DRL and improved DRL with attention mechanisms, the following observations can be made:

a) The improved method surpassed the final performance of the baseline (marked by the dashed line) at 0.2×10^{3} training episodes.

b) The standard deviation of average rewards decreased by 38% (quantified by the width of the shaded area).

c) The final convergence value improved by 20% (50→60), validating the enhancement of strategy stability by the attention mechanism.

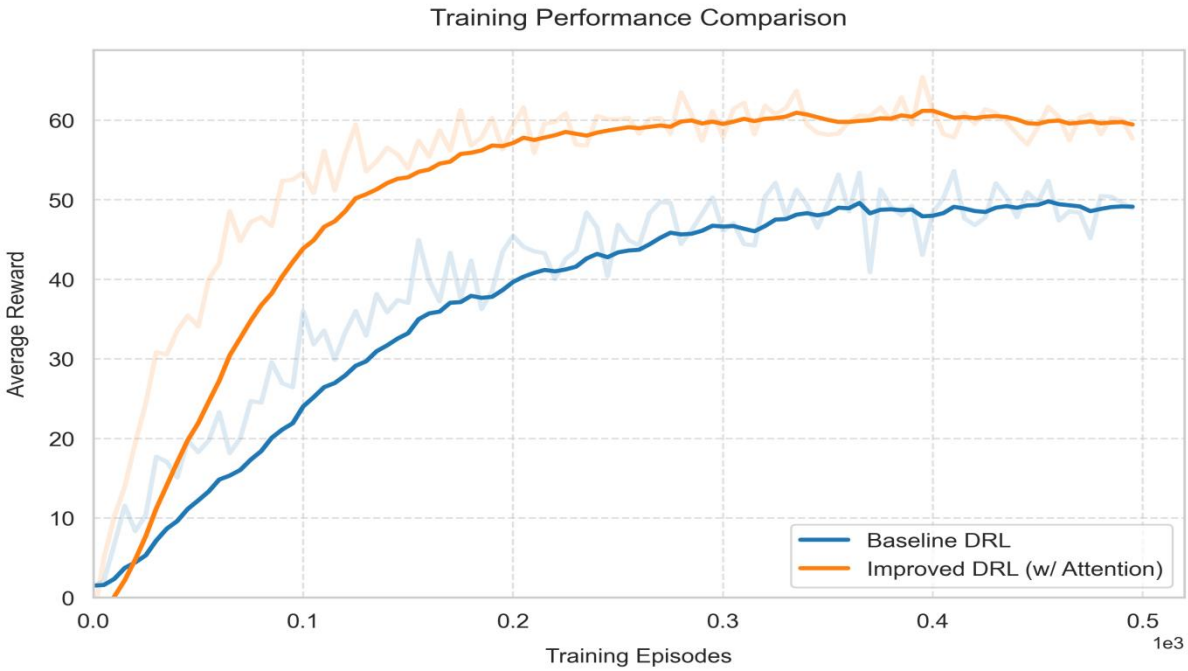

Figure 2: Comparative Analysis of Training Process Curves

Metric	Traditional DRL	Enhanced DRL	Improvement
Attitude Angle Error (RMS)	8.2°	5.7°	30.5%
Training Convergence Steps	420K	310K	26.2%
Energy Consumption	152	126	17.1%

Table 2:Expected Performance of Enhanced DRL

The experimental simulation results show that, in the energy efficiency comparison between passive twist and active twist, active twist driven by servos demonstrated higher energy efficiency in specific flight tasks, particularly under high maneuverability requirements. However, the application of traditional Deep Reinforcement Learning (DRL) in flapping wing control encountered bottlenecks such as redundant state spaces and unstable training, which limited its further adoption in practical applications.

To overcome these challenges, we introduced attention mechanisms into DRL. Attention mechanisms enable the agent to focus on key information when processing complex states, thereby improving learning efficiency and stability. By comparing experimental results before and after introducing attention mechanisms, we found that, within the same training cycle, the DRL control strategy with attention mechanisms showed significant improvements in performance metrics such as flight stability, energy efficiency ratio, and response speed.

In conclusion, this study validated the effectiveness of optimizing dynamic twist control strategies

for bio-inspired flapping wing aircraft based on machine learning through comparative analysis of experimental results under various conditions. Future work will further explore the adaptability of attention mechanisms in complex dynamic environments and investigate how to apply more advanced machine learning methods to the optimization of flapping wing aircraft control strategies.

References

[1] Guo Yan, Lü Heng, Ding Chunling, et al. Machine learning recognition of fractional-order vortex beam diffraction processes[J]. Acta Physica Sinica, 2025, 74(1): 101-108. DOI:10.7498/aps.74.20241458.

[2] Chen Jiali, Zhao Guoxiang, Yan Yayu, et al. Machine learning exploration of electron gas adsorption on zeolite molecular sieves[J]. Chinese Journal of Inorganic Chemistry, 2025, 41(1): 155-164. DOI:10.11862/CJIC.20240408.

[3] Shang Shuyi, Li Hongjia, Song Chen, et al. A review of machine learning-based KPI anomaly detection in internet service scenarios[J]. Journal of Computer Research and Development, 2025, 62(1): 207-231. DOI:10.7544/issn1000-1239.202330577.

[4] Tian Gen, Zhu Fuhong, Wang Wenyu, et al. Application of machine learning-based sensor monitoring in metal laser additive manufacturing[J]. Materials Reports, 2025, 39(2): 175-190. DOI:10.11896/cldb.23080174.

[5] Qi Jianan, Du Yuxuan, Li Likun, et al. Research on shear capacity of studs in steel-UHPC composite structures based on machine learning[J]. Journal of Southeast University (Natural Science Edition), 2025, 55(1): 146-153. DOI:10.3969/j.issn.1001-0505.2025.01.017.

[6] Wang Maocen, Zhang Lingxin, Zhong Jiangrong, et al. A machine learning-based method for rapid intensity prediction in meizoseismal areas[J]. Journal of Vibration and Shock, 2025, 44(2): 235-244. DOI:10.13465/j.cnki.jvs.2025.02.024.

[7] Deng Bin, Gong An, Wang Jiang. Machine learning-based modeling and prediction of human thermal comfort[J]. Journal of Tianjin University (Science and Technology), 2025, 58(3): 237-246. DOI:10.11784/tdxbz202407008.

[8] Fu Yu, Liu Taotao, Wang Kun, et al. A review of machine learning-based encrypted traffic classification[J].Journal on Communications, 2025, 46(1): 167-191. DOI:10.11959/j.issn.1000-436x.2025006.

[9] Hou Fang, Qi Xiaoning, Liu Ruichen, et al. Machine learning-assisted prediction of hydrocarbon molecular properties and high-throughput screening of fuels[J]. Chinese Journal of Energetic Materials, 2025, 33(1): 1-12. DOI:10.11943/CJEM2024276.

[10] Huang Zhongqing, Peng Shuang, Sun Deen, et al. Machine learning-assisted design of high-strength and tough (TiZrNbCrSi)N high-entropy nitride coatings[J]. Surface Technology, 2025, 54(1): 74-83, 160. DOI:10.16490/j.cnki.issn.1001-3660.2025.01.007.

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Genetic Modification Technology and Food Security: Opportunities, Challenges and Response Strategies

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Abstract: Against the background of global population growth, climate change and the increasing tension of arable land resources, how to ensure food security has become a major issue that needs to be addressed by the international community. As an efficient and precise means of genetic modification, transgenic technology has demonstrated remarkable potential in increasing crop yield, enhancing stress resistance and optimising nutritional quality. However, the large-scale application of this technology is still faced with scientific risks such as genetic drift and ecological balance disruption, as well as multiple challenges such as divergence of public opinion, ethical controversies, and lack of regulatory systems. Based on systematic literature research and case study analysis, this paper firstly compiles the major bottlenecks facing global food security and points out the shortcomings of traditional agricultural technologies in coping with extreme environments and resource scarcity; then it elaborates on the principles and successful practices of biotechnologies such as genetic modification and gene editing, and explores the advantages and constraints of these technologies in increasing agricultural yields and sustainable development; finally, it raises questions from the dimensions of technological research and development, public education, law and regulation, and international co-operation. Finally, the study proposes strategies in the dimensions of technology research and development, public education, law and regulation, and international co-operation, and emphasises the importance of multi-party collaboration and long-term monitoring to ensure the safe application and social acceptance of GM technology. The results of this study provide useful references for relevant policy makers, research institutions and the public to understand the opportunities and challenges of GM technology, and lay a theoretical and practical foundation for further improving the food security governance system and achieving the goal of global poverty reduction.

Keywords： Genetic modification technology, Food security, Gene editing, Ecological risk,International cooperation

1 Introduction

1.1 Background of the Study

Food security is a significant challenge confronting the international community. As the global population continues to grow, climate change intensifies, and arable land resources become increasingly scarce, all countries must navigate a critical balance between food production and ecological protection. According to a report by the Food and Agriculture Organization of the United Nations (FAO), the global population is projected to reach 9.8 billion by 2050. To meet the ever-expanding demand for food, agricultural production efficiency must increase by approximately 60 to 70 percent.[1] However, the production model dominated by traditional agricultural technologies has gradually revealed its limitations, including difficulties in responding swiftly to frequent extreme weather events, the spread of pests and diseases, land degradation, and water scarcity. These challenges severely hinder the sustainable development of agricultural production.

In recent years, transgenic technology has emerged as a highly efficient and precise method for genetic improvement, offering a significant solution to the challenge of global food security. This technology enables substantial enhancements in crop traits within a short timeframe through genetic recombination or gene editing. For instance, it facilitates the development of new crop varieties that exhibit high yields and increased resistance to pests, diseases, drought, and salinity. However, this technology is also met with considerable controversy regarding safety risks, social ethics, and policy regulation[2]. Consequently, determining how to maximize the benefits of transgenic technology while ensuring ecological and food safety has become a critical issue in the realm of global agricultural research.

1.2 Significance of the Study

By systematically analyzing the major challenges to global food security and the limitations of traditional agricultural technologies, this study explores the potential of genetically modified (GM) technology in agricultural production, as well as the various risks it encounters. The aim is to provide significant theoretical references and practical foundations for governmental decision-making, technological research and development (R&D) by scientific research institutions, and public education. Additionally, through comprehensive analysis and clear explanations, this study seeks to promote a rational understanding of GM technology among the public, reduce social misconceptions and biases, and foster a more open and scientifically informed public discourse. Furthermore, by employing a multi-dimensional analysis of strategies, this research can facilitate the healthy and orderly advancement of GM technology within a safe and manageable framework, ultimately contributing to the enhancement of global food security.

1.3 Research Methodology and Framework

This study employs a methodology that combines a literature review with case analysis. The literature primarily consists of authoritative academic journals from both domestic and international sources, as well as relevant policy reports issued by international organizations such as the FAO and CGIAR. This

approach integrates the promotion practices of genetically modified (GM) crops in selected countries and regions to conduct a thorough analysis of the effectiveness of GM technology and the actual challenges encountered.

The structure of the paper is organized as follows:

(1) Analysis of Food Security Challenges

An in-depth discussion of the primary challenges currently confronting global food security, as well as the limitations of traditional agricultural technology, is essential to establish a foundation for understanding the genuine needs for transgenic technology.

(2) Application of Transgenic Technology in Food Production

This text aims to systematically introduce the principles of transgenic and gene editing technologies, highlight typical successful cases, and explore their potential applications in enhancing food production efficiency and ensuring food security.

(3) Challenges to Food Security Associated with GM Technology

This text focuses on the scientific and technological challenges, social and ethical controversies, as well as the policy and regulatory bottlenecks associated with the application of genetically modified (GM) technology. It also aims to clarify the potential risks involved in the process of applying this technology.

(4) Strategies for Addressing Food Security Challenges Through GM Technology

Specific strategies are proposed to strengthen technology research and development, enhance scientific verification, improve public scientific knowledge, establish a comprehensive legal regulatory system, and promote international technical cooperation.

(5) Case Studies and Future Prospects

This study analyzes the practical effects of applying genetically modified (GM) technology, using specific international and Chinese local cases. It also addresses the challenges faced by this technology and anticipates future development trends in GM technology, aiming to provide practical support for the study's conclusions.

2 Analysis of food security challenges

2.1 Key challenges to global food security

Global food security is currently facing numerous significant challenges, particularly those posed by climate change and environmental degradation. According to the Food and Agriculture Organization of the United Nations (FAO) and the Intergovernmental Panel on Climate Change (IPCC), the global decline in agricultural production attributable to climate change has surpassed 20 percent over the past 30 years[3]. Frequent climate-related events, such as droughts, floods, and extreme heat, have substantially increased uncertainty in agricultural output and have severely threatened the stability of the food supply. Concurrently, the reduction of arable land due to soil degradation, water scarcity, and ecological damage has greatly restricted the geographical scope and scale of food production. Furthermore, many developing countries continue to face significant deficiencies in agricultural infrastructure, investment in scientific and technological innovation, and political and economic stability, which further exacerbate the vulnerability of local food supply chains[4].

At the same time, the continued rapid growth of the global population, projected to reach 9.8 billion by

2050, will exert enormous pressure on food security, indicating that the demand for food will increase by nearly 70 percent compared to current levels. Additionally, rapid urbanization has led to a reduction in the agricultural labor force, a loss of arable land, and shifts in agricultural production methods, resulting in a significant slowdown in food output growth. This challenge is further exacerbated by imbalances in international food trade, where countries with greater production capacity may also encounter difficulties in achieving timely and efficient allocation of food resources due to trade barriers or market volatility, thereby exposing poorer regions to a heightened risk of hunger[5].

2.2 Limitations of traditional agricultural technologies

Traditional breeding methods typically rely on natural crossbreeding and artificial selection, necessitating multiple generations of breeding and selection. This process can span years to decades and is significantly influenced by environmental changes and unforeseen factors. For instance, traditional maize breeding improvements generally require 6 to 10 years to select varieties that are well-suited to specific climatic conditions, pests, and diseases. This lengthy timeline severely limits agriculture's ability to adapt to rapidly changing environments[6]. Furthermore, the over-reliance on chemical fertilizers and pesticides in traditional agriculture, while capable of significantly increasing yields in the short term, has resulted in long-term ecological issues such as declining soil fertility, environmental pollution, and reduced biodiversity. In the Punjab region of India, for example, the prolonged and irrational use of chemical fertilizers and pesticides has exacerbated soil pollution, leading to a serious problem where farmland in some areas faces the risk of productivity degradation or yield reduction[7].

Therefore, in light of global population growth and a rapidly changing agro-ecological environment, traditional agricultural technologies struggle to respond swiftly to emerging challenges. Consequently, there is an urgent need to explore more efficient, precise, and sustainable agricultural technologies to achieve food security.

3. Application of transgenic technology in food production

As an important branch of modern biotechnology, transgenic technology mainly includes two major directions: transgenic breeding and gene editing.

3.1 Overview of genetically modified technologies

(1)Transgenic Breeding

Transgenic breeding refers to the process of acquiring specific desirable traits, such as insect resistance, drought tolerance, and high yield, by introducing exogenous genes into the genome of the target crop. This process typically involves the following steps[8].

Selection and Cloning of Target Genes: First, genes exhibiting desired traits are screened from various organisms and cloned using molecular biology techniques.

The construction of gene vectors involves inserting target genes into suitable vectors, such as plasmids, to facilitate their introduction into plant cells.

Gene Introduction: The target gene carried by the vector is introduced into the plant cell using

techniques such as the Agrobacterium-mediated method or the gene gun method.

Screening and Regeneration: Cells that have successfully integrated the target gene are selected through resistance screening and other methods, and are then induced to differentiate and regenerate into complete plants.

A typical example is the introduction of the insect-resistant gene from Bacillus thuringiensis (Bt) into maize, which enables the plant to produce proteins that are toxic to specific pests, thereby effectively resisting pest attacks.

(2) Gene editing technology

Gene editing technology, exemplified by CRISPR/Cas9 and other methods, facilitates trait enhancement through the precise modification of a crop's genome. The CRISPR/Cas9 system is based on the immune mechanisms of bacteria and comprises two primary components[8].

Cas9 Nuclease: An Enzyme That Cleaves DNA.

Guide RNA (gRNA) is a segment of RNA that is complementary to a specific target DNA sequence, directing the Cas9 enzyme to a precise gene locus.

It operates as follows.

The design of gRNA involves creating a guide RNA (gRNA) that is complementary to the target gene sequence.

The guide RNA (gRNA) binds to the Cas9 protein to form a complex.

DNA cleavage occurs when the complex, guided by the gRNA, is localized to the target gene site, and Cas9 cleaves the double-stranded DNA.

DNA Repair: The cell repairs the break in its DNA through its intrinsic repair mechanisms, during which specific genetic alterations may be introduced.

Unlike traditional transgenic breeding, gene editing technology does not necessitate the introduction of foreign genes; instead, it directly modifies the target gene, thereby minimizing the potential impact of exogenous genes on the ecosystem. Furthermore, advanced off-target detection and assessment methods can further mitigate the risk of uncertainty.

(3)Common features

The common feature of these two types of technologies is their ability to achieve targeted improvements in crop traits within a relatively short timeframe, overcoming the limitations of the lengthy cycles and low efficiency associated with traditional breeding methods. These technologies offer more efficient and precise tools for agricultural production and are anticipated to play a crucial role in ensuring food security and addressing environmental changes.

3.2 Successful Cases of Transgenic Technology

There have been numerous successful applications of genetically modified (GM) technology in agriculture, which have significantly improved the resistance, yield, and nutritional value of crops. Several representative cases are described in detail below.

(1)Bt maize and insect-resistant cotton flowers

Bt crops are developed by incorporating the insect-resistant gene from Bacillus thuringiensis (commonly referred to as Bt), enabling the plants to produce proteins that are toxic to specific pests. This genetic

modification enhances the plants' resistance to insect damage.

Bt Corn: Data from the United States Department of Agriculture (USDA) indicate that since the introduction of Bt corn in 1996, corn growers in the United States have significantly decreased their reliance on chemical pesticides, while average crop yields have increased by approximately 5 to 10 percent[9].

Insect-Resistant Cotton: The introduction of Bt cotton in India has significantly reduced losses for cotton farmers in pest-prone areas, increasing yields by up to 20 percent or more in certain regions. This improvement has correspondingly raised farmers' incomes, thereby effectively promoting local economic development[10].

In China, scientists have independently developed intellectual property rights for Bt insecticidal proteins, including monovalent, bivalent, and fusion gene technologies, as well as efficient gene conversion techniques. They have cultivated a substantial number of high-yield, high-quality, and insect-resistant cotton varieties with excellent adaptability. The widespread adoption and application of these varieties have allowed China to reverse its market share in just ten years, and by 2007, the country had achieved a completely dominant position.

(2)Drought- and salt-resistant crops

In response to the challenges posed by climate-induced drought and soil salinization, scientists have developed drought- and salt-resistant crops, such as rice and wheat, using transgenic technology and have planted them in pilot areas. Studies have demonstrated that the yields of these crops in drought-prone and high-salinity environments have increased by an average of 15 to 30 percent compared to traditional varieties, offering innovative solutions for food security in impoverished or extreme environmental conditions[11].

(3) ‘Golden Rice’ is a genetically modified rice variety designed to enrich the endosperm with beta-carotene, a precursor to vitamin A. This innovation seeks to address the health issues associated with vitamin A deficiency in developing countries. According to statistics, vitamin A deficiency results in the deaths of 670,000 children under the age of five each year[12].

Although genetically modified (GM) technology has demonstrated significant potential to enhance agricultural productivity and address environmental challenges, its application in the field of food security continues to face several obstacles. These challenges primarily exist at the scientific and technological levels, the social and ethical levels, and the policy and regulatory levels.

3.3 Failure cases

(1). Resistant pests and ‘superweed’ problems

Emergence of Herbicide-Resistant Weeds: Following the widespread adoption of herbicide-tolerant crops, such as glyphosate-resistant transgenic soybeans and corn, in the United States, certain wild weed species have rapidly developed resistance due to the prolonged use of single-mode herbicides. This has led to the emergence of so-called weeds, farmers are compelled to either increase the quantity of herbicides applied or opt for higher concentrations or more toxic alternative agents. This approach not only escalates production costs but also exerts greater pressure on the ecological environment[13].

Risk of Insect Resistance Decline: Some insect-resistant transgenic crops, such as Bt maize and Bt cotton, may experience a gradual weakening or complete ineffectiveness of their original resistance proteins against certain pests due to long-term selection pressure from pest populations. Once a pest evolves resistance, it becomes essential to implement strategies to slow the evolution of resistance. This can be achieved through crop rotation, the stacking of different insecticidal proteins, or the adoption of integrated biological management strategies. In the absence of a science-based resistance management program, the associated risks and costs can escalate significantly over time[14].

(2). Obstacles to the promotion of ‘Golden Rice’.

Obstacles at the Social and Policy Levels: Academics and international organizations generally view golden rice positively regarding its potential to address the public health issue of vitamin A deficiency. However, in certain countries or regions, public skepticism regarding the safety and environmental impact of genetically modified (GM) foods persists. This skepticism, combined with a stringent approval process, public opposition, and resistance from activists, has hindered the smooth commercialization of golden rice.

Insufficient Promotion Channels and Supporting Measures: Even in the approved regions, 'golden rice' seeds encounter high breeding costs, inadequate promotion channels, and insufficient training for farmers, among other practical challenges. In some economically underdeveloped areas, the absence of a comprehensive agricultural extension system and policy support results in the variety not effectively reaching farmers. Consequently, the technical potential cannot be fully realized, making it difficult to achieve the anticipated nutritional improvement effects.

(3). The plight of some Bt cotton growers in India

Early Success and Late Divergence: Following the introduction of Bt cotton in India, cotton yields initially improved significantly, with some regions experiencing increases of over 20% and a reduction in the use of chemical pesticides. However, over time, as seed prices rose and certain pests began to develop increased resistance, economic returns started to diverge in various areas[15].

Business Risks for Smallholders: The prices of Bt cotton seeds are relatively high, and seed retention rights are limited. Small farmers with insufficient capital and technical resources are likely to face financial difficulties if farming is poorly managed, counterfeit seeds proliferate, or crop yields unexpectedly decline. This highlights the lack of complementary measures, such as training for farmers, credit support, and market regulation, in the promotion of genetically modified (GM) crops, which ultimately exacerbates the potential risks associated with the application of this technology.

(4). Comprehensive reflection: GM technology is not ‘once and for all’.

The cases presented above demonstrate that the successful implementation of genetically modified (GM) technology necessitates multiple safeguards across scientific, regulatory, economic, and social dimensions. In the absence of supportive crop rotation systems, effective resistance management, agronomic training, and robust policy regulation, GM crops are unlikely to deliver the anticipated benefits in localized areas. Furthermore, they may contribute to new environmental challenges, such as the emergence of superweeds and the degradation of pest resistance, as well as economic issues, including high seed costs and unstable farmer incomes. Consequently, GM technology should not be viewed as a standalone solution; rather, it must be integrated with sustainable agro-ecosystem

management and sound policy support to minimize risks and achieve the objectives of stable yields and increased incomes.

4. Challenges to food security based on transgenic technologies

4.1 Challenges at the scientific and technological level

Firstly, large-scale cultivation of genetically modified (GM) crops may result in genetic drift, which refers to the hybridization of GM crops with wild relatives or traditional varieties. This process can adversely affect the stability of local ecosystems. Such gene flow may lead to genetic contamination, resulting in the unintended alteration of non-GM crops and ultimately impacting biodiversity[16].

Secondly, the potential impact of genetically modified (GM) crops on non-target organisms, such as pollinators and soil microorganisms, is not yet fully understood. While proponents assert that GM foods are safe, opponents express concern that most current safety studies are short-term and do not adequately assess the risks associated with long-term consumption of GM foods. Furthermore, the cultivation of GMOs may facilitate the transfer of genes from foreign varieties into conventional organisms, leading to genetic contamination.

In addition, although gene editing technology is considered a more precise tool, studies have indicated that off-target effects, albeit at very low frequencies, still occur and may lead to unexpected gene mutations. Therefore, it is crucial to mitigate these risks through rigorous molecular biology testing and evaluation.

In order to enhance the scientific reliability and sustainability of transgenic technology, research institutions should increase their investment in basic research, off-target detection technologies, and long-term ecological monitoring. Additionally, they should continuously improve technical tools and assessment methods.

4.2 Social and Ethical Challenges

There are significant differences in public acceptance of genetically modified (GM) foods. Some consumers express concerns about potential health risks and often rely on mass media or social networks for fragmented information, which can lead to cognitive biases or misunderstandings. Additionally, ethical controversies, such as whether GM technology is and the issue of patent monopolies, have sparked multi-level discussions and opposition across various cultures[17].

At the international level, several countries and regions have established relatively successful practices in public education and science communication. For instance, the United States promotes the science of genetically modified (GM) crops within communities through university Extension Programs. Additionally, many countries in the European Union host open days at official scientific research institutes, allowing the public to engage in gene editing experiments firsthand. Research has demonstrated that transparency of information and interactive science communication can significantly enhance public understanding and acceptance of GM technology.

Therefore, in promoting genetically modified crops, it is essential to establish an effective public communication mechanism. This involves actively listening to diverse perspectives, addressing misunderstandings, and fostering trust through scientific communication and education.

4.3 Challenges at the Policy and Regulatory Level

Currently, there are significant differences in the regulatory standards and enforcement of genetically modified (GM) technology and food across various countries. The United States, relying on empirical evidence, emphasizes scientific assessment and ex-post regulation. In contrast, the European Union adopts a more cautious approach, requiring strict prior approval and labeling systems. Emerging economies, such as China, focus more on public opinion and consumer rights while enhancing their regulatory frameworks. Meanwhile, some developing countries have yet to establish comprehensive risk assessment and labeling systems, resulting in inadequate consumer awareness and market confusion[18].

At the international trade level, regulatory inconsistencies among countries have led to resistance against genetically modified crops in some nations, which have established technical barriers. These challenges hinder transnational agricultural cooperation and trade. International organizations, such as the Food and Agriculture Organization of the United Nations (FAO), are working to promote the harmonization of regulatory standards and risk assessment methodologies to create a more favorable policy environment for the cross-border distribution and application of genetically modified crops.

Therefore, one of the key issues that must be addressed is how to effectively integrate the safety assessment and regulatory systems for transgenic crops on a global scale in order to reduce trade barriers.

4.4 The Impact of Intellectual Property Rights and Patent Monopolies

As research and development (R&D) of genetically modified (GM) crops often necessitates substantial investment in capital and human resources, intellectual property rights and patent protection play a crucial role in providing revenue security and incentives for innovation for research institutes or enterprises that possess core technology. However, while patents serve to protect inventions, they are frequently perceived as a ‘barrier to entry’ that can establish a de facto monopoly within the crop seed supply chain, thereby hindering technology access for small and medium-sized R&D organizations and farmers. Specifically, the following aspects warrant further exploration and in-depth analysis:

1. R&D costs and seed prices

Patent Layout and High Costs: International seed industry giants frequently possess the rights to utilize gene editing tools (e.g., CRISPR/Cas9) and essential transgenic trait genes through their extensive patent portfolios. Small and medium-sized enterprises, as well as research institutes, are often required to pay substantial royalties or acquire exclusive licenses for the secondary development or cultivation of transgenic varieties,The significant increase in research and development (R&D) costs is a critical factor.

Market Pricing and Profit Model: In light of substantial R&D and patent investments, large seed companies frequently establish higher seed sales prices to recoup costs and maximize profits as quickly as possible. This pricing model creates a considerable barrier for regions and producers with limited financial resources, thereby hindering the broader adoption of the technology across various geographical areas and crop varieties.

2. Seed retention and market competition

Prohibition of Seed Retention Clauses: Many genetically modified (GM) seed licensing agreements mandate that farmers purchase new seeds each planting season, prohibiting them from saving seeds from the previous year's harvest for future use. While this practice may be acceptable in economically developed regions, it poses a significant financial burden for small farmers in less developed countries, as the cost of purchasing new seeds annually can be substantial[19].Farmers' Rights and Patent Exhaustion The principle of patent exhaustion is well established in fields such as pharmaceuticals; however, it remains controversial in the seed industry. Given that crops naturally reproduce and regenerate, the challenge lies in protecting the legitimate interests of seed companies while respecting farmers' traditional rights, such as the right to save their own seeds. This issue has become a focal point of international discussions. Additionally, some countries and regions are exploring the concept of a right to save seed or are implementing exception clauses through legislation to balance the interests of farmers with corporate revenue.

3. Restrictions on Technology Diffusion and International Co-operation

Patent barriers elevate the technological threshold. Developing countries that wish to introduce or cultivate genetically modified (GM) crops often face the challenge of negotiating cross-border licenses for essential technologies. High costs and complex licensing agreements can create substantial resistance. Additionally, the lack of access to critical genes or gene-editing tools hampers research institutions' ability to conduct comprehensive research and development (R&D) independently, thereby limiting local technological innovation capacity.The 'North-South gap' and Sustainable Development: Patent monopolies have, to some extent, exacerbated the 'technological divide' between developed and developing countries. The latter often struggle to effectively adopt and implement genetically modified breeding technologies due to limited financial resources and weak negotiating power. As a result, they miss opportunities to enhance food production and resilience through technological innovation. This situation not only jeopardizes their own food security but also amplifies the risk of imbalances between global food supply and demand.

4. Possible Mitigation Paths and Policy Recommendations

Public Interest Research and Open Licensing: Governments or international organizations can establish special funds to support public interest research institutes in conducting genetically modified (GM) crop breeding. They should also encourage open or low-cost patent licensing within a defined scope to alleviate the burden on developing countries and small farmers. Differentiated Pricing and Local Breeding Capacity Building: In the context of global crop trade and seed industry collaboration, differentiated pricing mechanisms can be implemented to provide preferential patent licensing or seed supply programs for low- and middle-income countries. Simultaneously, local scientific researchers should be engaged in joint breeding efforts to enhance local technological capabilities and strengthen the supporting industrial chain. Reason: The revised text improves clarity, readability, and technical accuracy while correcting grammatical and punctuation errors.Balancing Mechanisms of Laws and International Treaties: The international community can negotiate exemptions or flexibilities for seed retention or compulsory licensing under specific conditions through platforms such as the Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS) and the International Union for the Protection of New Varieties of Plants (UPOV) within the framework of the World Trade Organization

(WTO). This approach aims to reconcile the demands of patent protection with the imperative of food security[20].

Overall, there exists an inherent tension within the intellectual property (IP) system between the incentives for innovation and the potential for market monopolies in genetically modified (GM) technology. Identifying a pathway that safeguards the interests of research and development (R&D) stakeholders while preventing the excessive exclusion of disadvantaged groups or underdeveloped regions has become a critical issue that urgently requires attention in the widespread promotion of GM technology. Achieving an appropriate balance between patent protection and fair competition through concerted efforts in policy, legislation, and international cooperation will offer more sustainable technological support for global food security.

5. Strategies to address the food security challenges of transgenic technologies

In order to effectively address the challenges faced by GM technology in the area of food security, a comprehensive strategy is needed in the following four areas.

5.1 Strengthen technological research and development and scientific verification

Firstly, research institutes and enterprises should strive to enhance gene editing and transgenic breeding technologies, particularly in the areas of off-target detection sensitivity and ecological assessment precision. This involves the development of more accurate gene editing tools and the refinement of environmental impact assessment methods to ensure the safety and sustainability of transgenic crops.

Secondly, it is essential to establish a systematic and transparent scientific verification system. This system should incorporate long-term ecological monitoring, toxicological analyses, and multidisciplinary cross-cutting studies to provide sufficient empirical support for the safety of genetically modified (GM) crops. For instance, China has recently approved several gene-edited and transgenic crop varieties designed to enhance crop yields and ensure food security.

5.2 Enhancing Public Education and Science Communication

The sustainable promotion of genetically modified (GM) technology cannot be achieved without public understanding and support. Government departments, research institutions, and the media should collaborate to enhance science communication, enabling the public to acquire more objective and systematic knowledge. This can be accomplished through community engagement activities, organizing exhibitions on GM topics, and utilizing new media platforms to conduct interactive quizzes. For instance, several universities in the United Kingdom regularly host inviting community residents and students to learn more about the GM research process in their laboratories. This initiative has significantly increased local public awareness of the safety and value of GM technology.

At the same time, public concerns should be addressed promptly, and the spread of rumors and information asymmetry should be minimized through the establishment of a transparent information dissemination mechanism grounded in scientific evidence and professional risk communication. Only in an environment of dialogue and trust can genetically modified (GM) technology be widely accepted by

society.

5.3 Building a Sound Legal and Regulatory Framework

In order to ensure the safe application of genetically modified (GM) technology, it is essential to establish a robust legal and regulatory framework.

The unification of regulations and standards: At the international level, there should be a concerted effort to promote the harmonization of safety assessment and labeling systems for genetically modified (GM) crops. International organizations, such as the Food and Agriculture Organization of the United Nations (FAO) and the World Health Organization (WHO), can develop guiding principles to minimize trade friction resulting from inconsistent standards among countries.

Improve the traceability and labeling system: establish a comprehensive traceability system that tracks products from field to table, while simultaneously implementing clear and easy-to-understand genetically modified (GM) labels on packaging. This will safeguard consumers' right to know and their right to choose.

A comprehensive environmental risk assessment is essential prior to the approval of commercial planting. This process should include multi-tiered biosafety testing and an environmental impact assessment. Additionally, dynamic monitoring must be conducted throughout the entire planting process to enable timely adjustments and improvements to management measures.

For example, Japan has implemented a stringent safety review and product labeling system for the regulation of genetically modified (GM) foods to ensure consumers' right to know and to promote food safety.

5.4 Promoting International Co-operation and Technology Sharing

Developing countries often encounter significant challenges in the research and development (R&D) and implementation of genetically modified (GM) technology. These challenges include a lack of funding, insufficient technical expertise, and inadequate infrastructure. International organizations, such as the Food and Agriculture Organization (FAO), the Consultative Group on International Agricultural Research (CGIAR), and various international foundations, should assist these countries in establishing scientific research and breeding platforms. They can enhance local breeding capacity through scientific research projects, training exchanges, and financial support.

In addition, scientific research institutions and multinational corporations in developed countries should adopt a more open approach regarding intellectual property rights and technology transfer. By appropriately lowering technological thresholds and costs, more underdeveloped regions can gain access to high-quality breeding materials and technical guidance. Only through global technology sharing and collaborative innovation can the long-term challenge of food security be fundamentally addressed.

For instance, China has recently released guidelines to promote the development of biotechnology, aiming to create gene editing tools and breed new crop varieties to ensure food security and enhance agricultural technology.

In conclusion, by strengthening technological research and development, enhancing scientific

verification, improving public education and scientific dissemination, establishing a robust legal and regulatory framework, and promoting international cooperation and technology sharing, the challenges posed by genetically modified technologies in the realm of food security can be effectively addressed. This approach will ensure that these technologies are safe and sustainable for the benefit of the global community.

6. Case Study: Genetically Modified Technologies in Practice to Address Food Security Issues

6.1 Successful Cases in Developing Countries

Promotion of Bt Cotton in India: Traditional cotton cultivation in India is frequently impacted by pests, such as whiteflies, which complicates efforts to enhance yield and quality. Since the introduction of Bt cotton, cotton yields have significantly increased in the initial stages, and the use of chemical pesticides has markedly decreased, leading to higher incomes for cotton farmers. However, this situation has also revealed new challenges, including the development of pest resistance and monopolistic pricing of seeds. This indicates that reliance on genetically modified (GM) technology alone is insufficient to address all the challenges within the industrial chain. Therefore, ongoing policy regulation and continuous research and development (R&D) are essential[21].

Project on Arid and Saline Areas in Africa: In certain arid and highly saline regions of Africa, the introduction of transgenic maize, rice, and other crops has led to a significant increase in stable crop yields. In pilot field experiments, multinational research teams have discovered that the average yield of these transgenic crops is 15 to 25 percent higher than that of conventional varieties in extreme environments. These practices offer valuable lessons for less developed regions in adapting to climate change and underscore the crucial role of international cooperation and technology sharing in the promotion of genetically modified organisms (GMOs)[22].

6.2 China's Exploration and Practice in GM Technology

As the most populous country in the world, China's need for food security is particularly urgent. In recent years, China has engaged in extensive exploration and implementation of genetically modified (GM) technology, achieving a series of significant breakthroughs. For instance, the transgenic insect-resistant rice varieties 'Huazhou 1' and 'Bt Rice,' developed by Huazhong Agricultural University, have been validated through field trials to increase crop yields by approximately 8% to 12% in pest-prone areas while reducing pesticide application by over 30%[23]. This achievement has led to large-scale demonstration plantings in Hubei, Hunan, and other regions, showcasing substantial economic and ecological benefits.

In addition, the insect-resistant transgenic maize 'Jingke 968,' developed by the Chinese Academy of Agricultural Sciences (CAAS), has undergone continuous testing and cultivation for many years in the Northeast region. Data from the test fields indicate that its yield has increased by approximately 10% to 15% on average[24]. Simultaneously, it has effectively reduced pesticide usage and the costs associated with pest control and prevention, thereby further safeguarding the stability of farmers' incomes.

To support the promotion and implementation of the technology, China has also made significant improvements to relevant laws and regulations. This includes the introduction of the Regulations on the

Safety Management of Agricultural Genetically Modified Organisms, along with other rules that govern the entire process of GM technology, from research and development to commercialization. Furthermore, the government has actively engaged in public science outreach to mitigate social misunderstandings and resistance, while enhancing the public's scientific understanding of GM technology[25].

Through these concrete practices, China has gradually explored a path for the development of genetically modified (GM) technology that aligns with its national conditions, providing an effective example and experience for addressing food security challenges.

7. Conclusion and outlook

7.1 Conclusions

Comprehensively analyzing this study's systematic examination of the challenges related to food security, the application of genetically modified (GM) technology, and the various obstacles it encounters, the following key conclusions can be drawn:

Genetically modified (GM) technology has significant potential advantages in addressing food security.

The potential of transgenic technology to enhance crop breeding efficiency, improve stress tolerance and environmental adaptation, and increase nutritional quality has been substantiated to a significant extent. For developing countries that lack access to high-quality breeding resources, genetically modified (GM) technology offers a crucial method for rapidly producing high-yielding and stress-resistant crops. This advancement can help tackle the challenges posed by water scarcity, soil degradation, and the proliferation of pests and diseases exacerbated by climate change. Additionally, emerging gene editing technologies, such as CRISPR/Cas9, have further reduced the breeding cycle, creating new avenues to combat hunger and poverty on a global scale.

Scientific Controversies and Social Risks

Despite the potential benefits of genetically modified (GM) technology, there are still risks and controversies at both ecological and social levels. On one hand, genetic drift, uncertain ecological impacts, and potential threats to the biodiversity of GM crops have not yet been fully assessed in all environmental contexts. On the other hand, the public has raised questions about the safety and ethical implications of GM foods. Information asymmetry and public opinion have contributed to significant resistance to large-scale commercialization. Balancing technological innovation with social acceptance through further scientific validation and risk assessment remains one of the core challenges in GM research and application.

Regulation and international cooperation are crucial.

In the context of globalization, food and agricultural trade are closely interconnected, making it imperative to establish cross-border and cross-regional safety assessment standards and regulatory systems. A robust and transparent traceability and labeling system can protect consumers' right to know and enhance market confidence. Additionally, international technical cooperation and data sharing can not only accelerate the research, development, and optimization of genetically modified (GM) crops but also promote the advancement of sustainable agricultural practices worldwide. This will have a profound impact on mitigating the food crisis and safeguarding both economic and ecological balance.

Therefore, the scientific community, policymakers, and the public must collaborate to ensure the healthy development and responsible application of GM technology.

7.2 Future Prospects

Under the impetus of a new wave of scientific and technological revolution, advancements in genomics, molecular biology, precision agriculture, artificial intelligence, and other emerging fields will enhance the efficiency and safety of transgenic breeding. Specifically, the application of high-throughput sequencing and synthetic biology will facilitate the screening and modification of target traits within a shorter timeframe, significantly improving crop yield, quality, and environmental adaptability. Furthermore, a precision agriculture system that integrates big data and artificial intelligence will optimize crop management and decision-making processes, reduce water and fertilizer inputs, minimize the use of chemical pesticides, and promote the efficient and sustainable utilization of agricultural resources and the environment.

Against the backdrop of climate change, population growth, and accelerated urbanization, no single technology can achieve a comprehensive breakthrough in addressing the food security challenge. Genetically modified (GM) technology should be integrated with other agricultural innovations, such as digital management, biological control, and ecological restoration, to create a holistic, multi-dimensional, and multi-level solution. By strategically planning planting systems, farmland ecosystems, and economic and social conditions, we can maximize the potential of GM technology in terms of yield enhancement, quality improvement, and loss reduction, all while prioritizing environmental protection and resource recycling.

At the same time, extensive and in-depth international cooperation and technology sharing will be crucial for establishing genetically modified (GM) technology in developing countries. Through global research and development (R&D) collaboration and the exchange of results, we can, on one hand, continue to enhance the safety assessment and regulatory systems for transgenic crops, thereby reducing ecological and social uncertainties. On the other hand, we can assist more underdeveloped regions in acquiring the necessary breeding technologies and production materials, thus creating new opportunities for poverty alleviation, nutritional improvement, and economic growth.

In conclusion, only through the full cooperation of the international community, robust institutional safeguards, and effective communication between the scientific community and the public can genetically modified (GM) technology play a significant role in ensuring food security and promoting sustainable development. Looking ahead, we must continue to enhance our understanding of GM technology and its environmental adaptation, while also fostering collaborative governance and social consensus. This approach will enable GM technology to serve as a solid foundation for addressing global food challenges.

References

[1]Food Security Information Network (FSIN), & Global Network Against Food Crises (GNAFC). (2024). GRFC 2024. Rome. Retrieved from https://www.fsinplatform.org/report/global-report-food-crises-2024/

[2]International Service for the Application of Agricultural Biotechnology(ISAAA),(2021).Global biotechnology/transgenic crop commercialisation dynamics in 2019. Chinese Journal of Bioengineering, 01, 114-119. https://doi.org/10.13523/j.cb.2012100

[3]IPCC. (2023). Climate Change 2023: Synthesis Report. Geneva, Switzerland: IPCC. https://doi.org/10.59327/IPCC/AR6-9789291691647

[4]Rezaei, E.E., Webber, H., Asseng, S. et al. Climate change impacts on crop yields. Nat Rev Earth Environ 4, 831–846 (2023). https://doi.org/10.1038/s43017-023-00491-0

[5]Wang, S., Bai, X., Zhang, X. et al. Urbanization can benefit agricultural production with large-scale farming in China. Nat Food 2, 183–191 (2021). https://doi.org/10.1038/s43016-021-00228-6

[6]Andorf, C., Beavis, W.D., Hufford, M. et al. Technological advances in maize breeding: past, present and future. Theor Appl Genet 132, 817–849 (2019). https://doi.org/10.1007/s00122-019-03306-3

[7]Pratiksha, P., & Sharma, P. (2020). Status of Environmental Pollution in Rural Punjab and its Management. International Archive of Applied Science and Technology, 11(4), 98-104. https://doi.org/10.15515/iaast.0976-4828.11.4.98104

[8]Yao, Z. P., Cheng, Y., Wan, H. J., et al. (2017). Application of CRISPR/Cas9 genome editing technology in plant genetic engineering breeding. Molecular Plant Breeding, 15(7), 2647-2655. https://doi.org/10.13271/j.mpb.015.002647

[9]U.S. Department of Agriculture, Economic Research Service (USDA ERS). (2024). Adoption of Genetically Engineered Crops in the United States - Recent Trends in GE Adoption. Retrieved from https://ers.usda.gov/data-products/adoption-of-genetically-engineered-crops-in-the-united-states/recent-trends-in-ge-adoption.aspx

[10]Krishak Jagat. (2024, October 2). The Journey of Bt Cotton in India: A Historical Overview and its Impact on Agriculture. Retrieved from https://www.en.krishakjagat.org/india-region/the-journey-of-bt-cotton-in-india-a-historical-overview-and-its-impact-on-agriculture/

[11]Khan, S., Anwar, S., Yu, S., Sun, M., Yang, Z., & Gao, Z. Q. (2019). Development of Drought-Tolerant Transgenic Wheat: Achievements and Limitations. International journal of molecular sciences, 20(13), 3350. https://doi.org/10.3390/ijms20133350

[12]Mallikarjuna Swamy, B.P., Marundan, S., Samia, M. et al. Development and characterization of GR2E Golden rice introgression lines. Sci Rep 11, 2496 (2021). https://doi.org/10.1038/s41598-021-82001-0

[13]Ofosu, R., Agyemang, E. D., Márton, A., Pásztor, G., Taller, J., & Kazinczi, G. (2023). Herbicide Resistance: Managing Weeds in a Changing World. Agronomy, 13(6), 1595. https://doi.org/10.3390/agronomy13061595

[14]Bruce E Tabashnik, Jeffrey A Fabrick, Yves Carrière, Global Patterns of Insect Resistance to Transgenic Bt Crops: The First 25 Years, Journal of Economic Entomology, Volume 116, Issue 2, A

pril 2023, Pages 297–309, https://doi.org/10.1093/jee/toac183
[15]Kranthi, K.R., Stone, G.D. Long-term impacts of Bt cotton in India. Nat. Plants 6, 188–196 (2020). https://doi.org/10.1038/s41477-020-0615-5
[16] Mou, W.Y., Jia, Yifan, Zhao, Zongchao, Guo, W.V. & Chen, F.J.. (2016). Research progress on the risk of exogenous gene drift in transgenic crops and its control technology. Journal of Ecology (01), 243-249. doi:10.13292/j.1000-4890.201601.033.
[17]Sikora, D., & Rzymski, P. (2021). Chapter 13 - Public Acceptance of GM Foods: A Global Perspective (1999–2019). In P. Singh, A. Borthakur, A. A. Singh, A. Kumar, & K. K. Singh (Eds.), Policy Issues in Genetically Modified Crops (pp. 293-315). Academic Press. https://doi.org/10.1016/B978-0-12-820780-2.00013-3
[18]National Academies of Sciences, Engineering, and Medicine. (2016). Genetically engineered crops: Experiences and prospects. Washington, DC: The National Academies Press. https://doi.org/10.17226/23395
[19]Granieri, M. (2016). Genetically Modified Seeds, Intellectual Property Protection and the Role of Law in Transnational Perspective. In: Bellantuono, G., Lara, F. (eds) Law, Development and Innovation. SxI - Springer for Innovation / SxI - Springer per l'Innovazione, vol 13. Springer, Cham. https://doi.org/10.1007/978-3-319-13311-9_6
[20]World Trade Organization. (1994). Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS Agreement). Geneva: WTO.
[21]Peshin, R., Hansra, B. S., Singh, K., Nanda, R., Sharma, R., Yangsdon, S., & Kumar, R. (2021). Long-term impact of Bt cotton: An empirical evidence from North India. Journal of Cleaner Production, 312, 127575. https://doi.org/10.1016/j.jclepro.2021.127575
[22]Kumar, K., Gambhir, G., Dass, A. et al. Genetically modified crops: current status and future prospects. Planta 251, 91 (2020). https://doi.org/10.1007/s00425-020-03372-8
[23]Chen, X. J., He, S. L., Cheng, K. L., et al. (2003). Impact of transgenic Bt insect-resistant rice on the biological community of paddy fields. Journal of Sichuan Agricultural University, 21(2), 185-186.
[24]CHEN Chuan-Yong, ZHAO Jiuran, WANG Yuandong, WANG Ronghuan, XU Tianjun, LV Tianfang... & Cheng, Guanglei. (2018). Effects of nitrogen fertilizer reduction on nitrogen efficiency and yield of Jingke 968 and Zhengdan 958. Maize Science (03), 121-127. doi:10.13597/j.cnki.maize.science.20180320.
[25]State Council of the People's Republic of China. (2001). Regulations on Administration of Agricultural Genetically Modified Organisms Safety (Decree No. 304). Retrieved from https://faolex.fao.org/docs/pdf/chn52814E.pdf

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Analysis of the thought and art of Bai Juyi's "Song of Long Hatred"

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Abstract: The idea of the song of long hatred is mainly based on the "resentment and indignation, anger and sinking" in the song of long hatred, and is formed by describing the background of the era and the social reality in which the poet lives. The content of his poems profoundly reflects the tragic marriage, the miserable fate of weak women, the sadness of the people's voices, and the spiritual depression and suffering suffered by the working people at that time. This paper discusses Bai Juyi's artistic thought and main views of "Song of Long Hatred" from four aspects: first, "grievances"; The second is "irony blending, mournful twists and turns", compared with most of Bai Juyi's realist works, his masterpiece "Song of Long Hatred" deviates from history in a sense; Third, the focus of its creation is the love tragedy of Li and Yang, with "love" as the theme of creation, and its meaning also belongs to sentimental "amorous poetry"; Fourth, from a historical point of view, it changes with the times, with the author, and with the situation of the poem.

Key words: "Song Of Long Hatred"; Bai Juyi; Love Tragedy; Ideological Connotation; Artistic Features

1. Introduction

As a representative poet of ancient realism in China, Bai Juyi's poems are rich in content, different forms, and clear in language, especially the long narrative poem "Song of Long Hatred" as a representative work. In "Song of Long Hatred", it describes the social reality of the Anshi Rebellion caused by the monarch Tang Xuanzong's addiction to alcohol and the abandonment of the government, and also highlights the poignant and pathetic love story of Tang Xuanzong and Yang Yuhuan. For the description and expression of the theme of "Song of Long Hatred", there are mainly three types of views: irony, double theme and love. The theory of irony is a satire and criticism of the absurd and extravagant court life of the Tang rulers; The theory of love can be said to be a kind of sympathy and admiration for the sincere love of Tang Xuanzong and Yang Yuhuan; The dual theme theory argues that it has ironic criticism and sympathy.

2. An overview of Bai Juyi's life and ideological connotation

"Song of Long Hatred" is a long narrative poem written by Bai Juyi when he was thirty-five years old, and it is his proud work when he was in his prime, showing the author's extremely rich thoughts and feelings. For more than 1,000 years, everyone has different understandings, and some people think that this is a work that praises Li and Yang's love for loyalty and single-mindedness; Although the author classifies it as a "sentimental poem", in the nature of its content, it still belongs to the category of "allegorical poetry". There are also many people who think that in the poem, the front is an allegorical and the back is a praise, and the theme is twofold, or contradictory.

2.1 The historical evolution of Bai Juyi's "Song of Long Hatred".

A little investigation of Bai Juyi's life shows that Bai Juyi is actually a person who was deeply influenced by the ideas of Confucianism, Buddhism, and Taoism, and this thought has specific manifestations in different stages of his life. Here, in order to better narrate, I will roughly divide Bai Juyi's life into the following three stages:

2.1.1 From the seventh year of the Tang calendar to the fifth year of Yuanhe

In the seventh year of the calendar, Bai Juyi was born in a small and medium-sized class of "Shidun Confucianism" bureaucratic family. At the age of 29, he was admitted to the Jinshi, at the age of 30, he was admitted to the Hanlin Academy, and at the age of 35, he was a shining rising star in his career. During this period, he strongly advocated the reform of current politics with a sense of social justice and political initiative as the starting point. In terms of literary improvement and development, he also actively advocated the New Yuefu Movement, and put forward the slogan "articles are written for the time, songs and poems are written for things", for which he also wrote many "radical and straightforward" allegorical poems, such as "Guanjiamai", reflecting the suffering life of the people, such as "Chongfu", "Du Lingsuo" and "The Charcoal Seller" indict the dark officialdom of the same stream and pollution, highlighting the hard life of the common people, or simple or easy to understand or fascinating or exciting, These works all extensively deal with the social injustice of the Tang Dynasty and the hardships and hardships of the people's lives after the Anshi Rebellion.

2.1.2 Yuan and 6 years to Yuan and 11 years

During this period of time, Bai Juyi's life development has also changed greatly. The death of his mother, and his own demotion to Jiangzhou Sima for overstepping his duties, these two huge changes are a huge turning point in life development and thinking, so the poet has also slowly shifted from the great love of "helping the world" to the self-preservation of "being alone", and slowly transformed in the change of his career. Compared with his early years, his enthusiasm for participating in politics began to fade, and he gradually wrote more leisurely and sentimental poems, such as the famous "Pipa Xing".

2.1.3 yuan and 12 years later

During this period, Bai Juyi asked the imperial court to be released, and successively served as the assassin in Zhongzhou, Hangzhou, and Suzhou. He asked about Buddhism, and his interest in a leisurely and quiet life began to sprout, and in his later years, he called himself "Xiangshan Layman" because he lived in Xiangshan. It has completely walked towards the road of leisure, ease and tranquility.

2.2 The composition of Bai Juyi's "Song of Long Hatred".

Bai Juyi uses historical celebrities, myths and legends as materials, and through artistic processing and modification, he wrote a masterpiece called "Song of Long Hatred", which describes a tragic and poignant love tragedy between Tang Xuanzong and Yang Guifei, showing a historical picture of suffering and glory, and telling a moving life story[1]。 At the same time, the author also recreates the real life with his unique artistic techniques, which deeply moves the readers. "Song of Long Hatred" consists of four parts:

The first part: from "The Han Emperor Focuses on Color and Thinks of the Country" to "The King of the Sun Sees Enough" opens the prelude, describing how Tang Xuanzong re-colored and how to seek color before the Anshi Rebellion, and finally got Yang Guifei. After Yang Yuhuan entered the palace, he was deeply favored, relying on the favor he received, the family was rewarded, and his status also rose, while Xuanzong was obsessed with singing and dancing, and lived a debauched and uninhibited life. The first sentence "The Han Emperor is heavy on the country, and Yuyu has been unable to ask for it for many years." He was even more blunt, pointing out that Tang Xuanzong was a lustful monarch, which laid the foundation for Yang Guifei's appearance and favor. In terms of artistic effect, it leads the whole text and lays the foundation for the development of the whole story. The content is repeatedly rendered, especially after Tang Xuanzong got Yang Yuhuan, he indulged in wine, and to a certain extent, it also laid the foundation for the later development of the story.

Part 2: From "Yu Yang Mo Agitated" to "Looking Back at the Blood and Tears and Flow". The Anshi Rebellion led to the tragic ending of Li and Yang's love. "Yu Yang Mo agitated the ground, shocked the neon clothes and feather clothes song" is a continuation of the above, the author at this time turned his pen, using the series of verbs "moving the ground" and "shocking" to imply that the war was about to break out, reflecting the seriousness of the Anshi Rebellion. At this time, the rhythm and style of the whole poem change from soft and tactful to tense and solemn, which is completely different from the cheerful atmosphere in front of it, forming a sharp contrast. In this section, the author depicts the life and death feelings of Xuanzong and Yang Guifei with exquisite brushwork, which can neither be abandoned nor irretrievably reconciled.

Part 3: From "Huang Ai Scattered Wind and Depression" to "The Soul Has Not Come to Dream". Write about Tang Xuanzong's self-blame, guilt and deep thoughts for Yang Guifei after she died. "Huang Ai is scattered and the wind is sluggish, and the cloud stack lingers in the Sword Pavilion. There are few pedestrians under Mount Emei, and the flag is thin without light. These paragraphs highlight the description of the scene, among which "Feng Xiaosuo" is written about the autumn wind, creating a bleak and sentimental scene. In this way, Xuanzong's mood at this time is expressed, and the "lightless" and "thin" present an intertextual effect, rendering a sad and bleak atmosphere, so as to set off the character's state of mind at this moment.

Part 4: From "Linqiong Taoist Hongduke" to the end of the text. The poem records the process of Xuanzong sending people to find the concubine, and after the concubine became an immortal, he asked the Taoist to entrust the token to Xuanzong to show his memories and remembrances of the beautiful love in the past. The permanent parting of Li and Yang and their painful thoughts for each other have brought the tragedy of their love to a new height. When reading the last four lines of this poem, the reader will be deeply touched and then resonate. From love to hate, the more the pursuit and longing for tears are filled, the more tragic the separation becomes, and the more helpless it causes to the human heart, the more delicate the depiction of feelings becomes.

2.3 The status of Bai Juyi's "Song of Long Hatred".

In this long narrative poem, the author uses a combination of conciseness, imagery, narrative, scene writing, and lyricism to make it lyrically present the characteristics of looping and repetitive. Sometimes, the poet will put his thoughts and emotions into the scene, and use the refraction of the scenery to set off the mood of the characters; At the same time, he will capture the scenery and objects around the characters, express his emotions through his feelings, and render them layer by layer, so as to express the indescribable emotions hidden in his heart, which are just right.

3. The background of the creation of "Song of Long Hatred".

3.1 Appropriate social conditions

Bai Juyi was the most famous poet of the Tang Dynasty, second only to Li Bai and Du Fu. In "The Poet's Subject and Object", Zhang Wei divides the poets with unique styles into unique style genres. Different genres, influenced by regions and cultures, have formed different creative styles. For example, Meng Jiao's style strives to be strange, but Bai Juyi is not like this, which means that his poems have a far-reaching and lasting influence. Bai Juyi himself divides his poems into four major types: allegorical poems, sentimental poems, leisure poems, and miscellaneous poems. Of these poems, he valued allegorical poetry the most. The original meaning of the word sarcasm is to persuade the other party in a tactful way, to persuade the other party, which is irony. The ancients thought that this expression was similar to the "Book of Songs", especially Bai Juyi's summary of the biggest feature of "beauty and thorn Xingbi" in the "Nine Books of the Yuan".

3.2 The characteristics of Bai Juyi's "Song of Long Hatred".

"Long hatred" is the theme of the poem, the center of the story, and a fire of the heart deeply rooted in the poem. As for "hate" and why "long hate", the poet does not directly describe and describe it, but uses his poems to present it layer by layer, allowing readers to ponder, taste and experience it by themselves.

The first sentence of this poem: "The Han Emperor re-colored the country", seems ordinary, as if the story began here, because these seven words are the finishing touch of the whole poem, it not only shows the tragic component, but also plays a role in dominating the whole poem, affecting the artistic

effect of the whole poem[2]。 Then, he used the most simple words to tell how Tang Xuanzong emphasized color and sought color before the Anshi Rebellion, and finally won Yang Guifei "Looking back and smiling, the six palaces have no color". This poem writes that Yang Guifei is good-looking, and she is deeply favored after entering the palace. However, all of this was the fuse of the Anshi Rebellion. The section "Yu Yang Mo Agitated and Broke the Song of Ni Clothes and Feathers" discusses the internal reasons for the "long hatred" and lays the foundation for the development of its story. The author presents the heroes and heroines in the story in a real way: one is the emperor who is heavy on color and light on the country, and the other is a coquettish and pampered concubine. At the same time, it also implies that Tang Xuanzong's addiction to wine will eventually lead to trouble. The whole story is exquisitely conceived and full of practical significance.

3.3 The spiritual characteristics of Bai Juyi's "Song of Long Hatred".

The poet integrates his own thoughts and emotions into the scene, using the landscape to set off the mood of the characters; Capture the scenery and characters around the character, express his feelings through these scenes, and render layer by layer, expressing the unspeakable feelings in his heart to the fullest. When Tang Xuanzong fled to the southwest, there were yellow dust, plank roads, high mountains, dim sun, dim flags, and bleak autumn breezes along the way. The country's great rivers and mountains are beautiful, but in the eyes of Tang Xuanzong, the green mountains and green waters reveal a sad loneliness. The beauty of nature had to be appreciated with a serene state of mind, and he himself did not, which exacerbated his inner anguish. This is to contrast the sadness through the beautiful scenery and further deepen the emotion. The moonlight in the palace, the bells on a rainy night, are all so moving, the poet grasps those ordinary and symbolic things, and makes people fall into a situation of sadness and sorrow, and those voices, voices, voices, words, tones, are all so. All kinds of factors made him write a sense of loneliness in this poem, and every sentence was written very sadly, so reading such a work, I can best understand the poet's helplessness and inner sorrow[3]。

From the stretching yellow dust to the verdant Shu Mountain, from the palace in the rain to the returning memorial, from day to night, touching things everywhere, people who miss from time to time. It is repeatedly rendered from multiple angles, setting off Xuanzong's painstaking remembrance and pursuit of the concubine. The poet uses this layer-by-layer rendering technique to express his emotions again and again, making the characters' thoughts and emotions more profound, "delicate in texture", and more artistic.

4. Analysis of the artistic characteristics of "Song of Long Hatred".

4.1 Exquisite and unique artistic conception

The artistic charm of this narrative poem lies in its ingenious and unique artistic ideas. Based on historical facts, the author carefully conceived and interpreted the love tragedy of Li and Yang in a magnificent, twists and turns. The word "long hatred" at the end of the article can be said to be the main theme of the poem. The poet first describes Tang Xuanzong's greed for beauty, and then describes Li and

Yang's debauchery and extravagance. This led to the Anshi Rebellion, the tragedy of the fate of the nation, and the tragedy of the love between Li and Yang. They are not only the creators of tragedy, but also the bearer of tragedy. Bai Juyi's artistic ideas make the theme of "Song of Long Hatred" richer, more profound and thought-provoking. It is precisely because of this clue that Tang Xuanzong's infinite nostalgia for Yang Yuhuan after his death is more vivid. In order to highlight the theme of "long hatred", the author is no longer limited to history, but uses rich imagination to fabricate the storyline of the monks looking for the concubine all over the world, and creates the touching story of Yang Yuhuan's rebirth in the fairyland, and the touching story of gifts, which makes the tragic plot change and become more legendary[4]。

4.2 Romantic Artistic Techniques

He brings the story to life with an emotional brushstroke, and it depicts the miracle of love in a romantic style. And put forward the beautiful expectation of "heaven and earth will meet", which makes this love tragedy have strong practical significance and universality, so that it can be pinned between heaven and earth. "Song of Long Hatred" is continued and developed from the "Book of Songs", and has also had a great impact on the legends of the Ming and Qing dynasties.

4.3 The integration of narrative, lyricism and description

"Song of Long Hatred" is a narrative poem, which has a variety of forms of expression such as narrating stories, describing scenes, and expressing emotions, and is good at integrating these three forms together. He described the process from Anshi's rebellion to Xuanzong's escape, to Ma Weipo's forced death of the concubine, and then to the loneliness and sadness of his later years and his longing for Yang Guifei. This scene all reveals the immortal love between Tang Xuanzong and Yang Guifei.

The narration of the author's whole poem is not a pure objectivist narrative, but incorporates the poet's rich and strong thoughts and emotions. He was critical of Tang Xuanzong's absurdity and misappropriation of the country and Yang Yuhuan's pampered and arrogant behavior, and showed strong sympathy and admiration for their love tragedy. The poet may put his thoughts and feelings into the scenery, and set off the character's state of mind at the moment through the scenery; You can also choose things and scenery with certain characteristics, and express your inner world by describing the mood of these things and scenes, or write sadness with music, or write musicality with sadness.

The poem has twists and turns, detailed descriptions, tactful rhythms, interconnected, fluent language, harmonious rhyme, and catchy reading. The poetry is very strong, and there are many good sentences that are widely circulated. In addition, proper detail and meticulousness are also a major feature of this poem. The description of the Anshi Rebellion, a major political event in the poem, is only summarized by "Yu Yang's agitation and breaking the song of the neon clothes and feathers", but does not mention the causes and consequences of the Anshi Rebellion and describe it in detail. After Tang Xuanzong was given Yang Yuhuan to die due to Ma Wei's change, his deep thoughts about her made the poet use a lot of space to describe it in detail and profoundly, so that the writing can highlight the key

points and highlight the theme more through the changes in the emotions of the characters, so as to achieve the role of deepening the theme[5]。

"Song of Long Hatred" is a narrative poem with strong lyrical color, which uses the unique narrative, description and lyrical techniques of classical Chinese poetry to integrate narrative, scene writing and lyricism, forming a looping feature in lyricism. Sometimes, the poet will put his thoughts and emotions into the scene, and use the refraction of the scenery to set off the mood of the characters; Sometimes, he will capture the scenery and characters around the characters, express his emotions through his feelings, and render them layer by layer, showing the indescribable emotions that he has hidden deep in his heart just right. Tang Xuanzong fled to the southwest, along the way is full of yellow dust, plank roads, high mountains, the sun is dim, the flag is dim, the autumn wind is bleak, it is with the sad autumn scenery to set off the poet's sorrow[6]。 In Shu, the mountains and rivers are beautiful, day and night do not forget, the mountains and rivers in Shu are a beautiful scenery, but in the eyes of Tang Xuanzong, the "green" mountains and "blue" water are sad. It is to express sadness through beautiful scenery and further deepen the emotion. In addition, in the poem, the author also uses the artistic technique of romanticism. With the death of Yang Guifei, the story of the chapter should have ended, but the poet's pen transferred their love story to continue to extend, deducing the immortal chapter of unfinished human and ghost love.

4.4 The beauty of language and rhythm

The most noteworthy thing is that this long narrative poem is fluent and graceful in language, gorgeous and beautiful, and neat in structure, with harmonious syllables and vivid images. Coupled with a variety of different rhetorical devices, the language of the poem has a unique charm and appeal. For example, when Yang Yuhuan was selected into the palace, he described his charming and moving appearance, "looking back and smiling, the six palaces have no color", only two lines of poetry vividly express the mood of the characters. In order to enhance the formal beauty of language, the poem also uses a variety of rhetorical devices such as borrowing, metaphor, contrast, duality, and truthfulness.

5. The ingenuity and profundity of the creation of "Song of Long Hatred".

5.1 Reflects Li Yang's deep sympathy for love

In the poem, Bai Juyi's satire on Xuanzong's obsession with women and absurdity and debauchery is very wonderful and profound. In this regard, we can give two examples to get a glimpse of the leopard: one is to use exaggerated brushwork to ruthlessly expose the shamelessness and fornication of the monarch. "The spring night is bitter and the day is short, and the king will not be early from now on." Reading the opening sentences, a picture of court fornication first catches our eyes, Bai Juyi's extremely exaggerated technique contains the historical inevitability of the collapse of the Tang Dynasty. The second is from "the Han Emperor is heavy on color and thinks about the country" to "not reborn male and reborn female". The description reflects an extremely profound historical content. Throughout Chinese history, there have been a few times in which literary works have reflected the abnormal social

phenomenon of "not giving birth to a man but giving birth to a woman" in a patriarchal society: the Qin people believed that the result of giving birth to a boy was a pillar of bones; The Tang believed that giving birth to a boy was like a hundred grasses with no bones left, and that giving birth to a girl was for the promiscuous pleasure of the ruling class. It can be seen from this that the birth of a boy or a girl in Chinese history has never been a personal problem of the people, but an extraordinary choice forced by the harsh social order and vicious forces[7]。 As the dislocation between male and female love becomes stronger, the criticism of unreasonable reality becomes stronger, and the meaning behind it becomes more profound, giving readers more room for imagination and thinking.

5.1.1 Detached from the folk sympathy and nostalgia for Li Yang's love

When it comes to "The Song of Long Hatred", you will be moved by the beautiful sentences in the poem, such as "I wish to be a winged bird in heaven, and I wish to be a branch in the earth." The oath is also like "Gazing at the king with affection, a farewell voice and two slim." "Life and death. For Xuanzong, there are 3,000 beauties in the harem, why do you love Yang Yuhuan? The sentence "natural beauty is difficult to give up, once chosen on the king's side" in the poem may only mean that Xuanzong's love for Yuhuan stays at the level of beauty.

Morality, ethics and thoughts and feelings have actually become the two key points around which Bai Juyi's life and literary creation revolve. Starting from Bai Juyi's family and life worldview, this paper deeply examines Bai Juyi's ideological structure in the two worlds of Shijin and feelings. Of course, this is only one aspect of Bai Juyi's moral and emotional predicament, on the other hand, he often contradicts and even opposes each other in the worldview of morality and emotion: Bai Juyi accepts the nourishment and edification of traditional Chinese culture, but leaves the world with the impression of "ambition and benevolence". He advocated actively joining the WTO, making meritorious contributions, and doing something for the common people of the world, but when he was squeezed out and suppressed by the feudal bureaucracy, "the world will not be open from now on" and he wisely protected himself; He deliberately transcended the shackles of the world and pursued freedom and happiness, but in the face of the feudal system of etiquette and religion, he "changed his old heart" and surrendered[8]。 Bai Juyi is multi-faceted, he said when he saw the charcoal seller in the south of Chang'an City, "The poor body is single, and the heart is worried about the cold weather." It is abrupt, and the "long hatred of spring is nowhere to be found, and I don't know how to turn here" sung in the grass hall of the Lushan Flower Path, which is quiet and free. The pain that Bai Juyi encountered in his life was the pain encountered by a great ancient Chinese intellectual, and this pain was noble, happy, and inevitable. Bai Juyi's historical limitation lies in his failure to see the dialectical laws of the identity of contradictions, the nature of struggle, the position of confrontation in contradictions, and the mutual transformation of contradictions, but this does not hinder Bai Juyi's historical achievements in reading, being a person, and literary creation, as well as his historical position in the history of Chinese literature.

5.1.2 Infiltrate Bai Juyi's strong thoughts and feelings and rich imagination

In "Song of Long Hatred", I think the most unique and skillful artistic technique that can distinguish it from other works - the correspondence between fiction and reality. After describing the tragic death of the concubine in front of Ma Weipo and the empty and deserted place of laughter in the past, Bai Juyi did not blindly express how Tang Xuanzong felt heartache about it, but turned his pen in the later text, "In order to feel the king's thoughts, he taught the monks to look diligently." Tang Xuanzong came to the illusion and saw the concubine with "snow-skinned flowers and uneven appearance" again, or the same appearance as in his memory, and the concubine in the fantasy world had already missed Xuanzong to the bone, "Yurong is lonely and tears are dry, and pear blossoms bring rain in spring." However, even in the fantasy world, it can only have a short-term beauty, and after a long farewell, the sound is slim, so the old things will be talked about affectionately, and the words will be sworn to separate, and the world will be separated from hatred. This affectionate expectation and tragic parting suddenly added a lot of tragedy to the story.

The reunion in the fantasy world is thrilling, but the joyful reunion is not real. It's not so much an illusion, it's more like what Xuanzong thinks, even if I can meet the concubine again, show her my affection, leave this love as deep as the sea, and make this vow that spans life and death, it can be regarded as a wish[9]。 However, even if it is a brief encounter, it can only exist in fantasy, and then looking back on this present world that I can't bear to look at directly, the pain in my heart is even more indescribable. The brilliance of this writing technique lies in the fact that the article does not devote the entire length of the second half to a positive description of Tang Xuanzong's suffering, but after describing a sad scene, it narrates this false joyful reunion to achieve a more touching artistic effect than simply expressing the suffering in reality[10]。 This is the excellence of Bai Juyi's creation of this poem, and it is also the reason why "Song of Long Hatred" has been passed down through the ages, and it is its soul.

The first pleasing thing about "Song of Long Hatred" is the graceful and moving story in the poem, which is an ingenious and unique artistic idea. The word "hate" in the poem is very touching, and it seems that this story ends here. But the poet's words turn sharply, but it is a different realm, under the wings of imagination, creating a beautiful world, developing the tragic story to a climax, making the whole story more complex and full of waves. This change is unexpected, but it is also reasonable. Because the subjective desire and the objective reality are constantly in conflict and conflict, the poem fully expresses the complex psychology of the protagonist and makes the story more beautiful and moving. This makes the whole poem look more like a kind of aria, a cry, a simple pursuit of the poet.

In this long narrative poem, Bai Juyi uses concise words, vivid imagery, and a combination of narrative and lyricism to tell the tragedy of the love between Tang Xuanzong and Yang Guifei in the Anshi Rebellion: they ruined their love because of their own rebellion, and the pain caused by this spirit is endless[11]。 Tang Xuanzong and Yang Guifei are both historical figures, but the poet did not bind them to history, but used some traces of history to extract a twists and turns from folk legends and folk songs. Because the stories and characters in the poems are artistic, they are a complex and real reflection of people in real life, so they can ripple in the hearts of readers of all generations.

5.2 The organic unity of truth, goodness and beauty forms the finishing touch

5.2.1 The authenticity of the feelings described

"Song of Long Hatred" expresses the poet's sincere feelings, on the one hand, it praises Li Yang's loyal love, and on the other hand, it does not deliberately beautify Li Longji, but reveals the true feelings of Li and Yang's love.

The "Reign of Kaiyuan" is a good example. The poets' yearning and nostalgia for the "rule of Kaiyuan" is first of all the affirmation and praise of the "rule of Kaiyuan" in the early days of the reign of Xuanzong of the Tang Dynasty, not only Bai Juyi, but also Du Fu. In the early Tang Dynasty, Xuanzong was a man with political talent, and the achievements of the country's peaceful development and the people's living and working in peace and contentment were affirmed by history. Therefore, we cannot deny Bai Juyi's deep sympathy for the tragedy of Li and Yang because of Bai Juyi's irony of his later emphasis on color and misconception.

5.2.2 Ideological tendencies

In order to understand the ideological tendency of "Song of Long Hatred", it is a fundamental premise whether we should look at the love between Li and Yang dialectically from the perspective of history and literature. At the same time, this is a very important question. And the two characters in "Song of Long Hatred" are very different from their real historical situation. Historically, the relationship between Li and Yang was usually critical, and Tang Xuanzong's neglect of government because of his excessive favor of Yang Guifei was inseparable from the series of consequences caused by the subsequent Anshi Rebellion. Therefore, from a historical point of view, we can only draw such conclusions: first, the negation of the love tragedy of Li and Yang; The second is to give affirmation because of the irony of Li and Yang. But the complication of the matter is that literature is not the same as history. What's more, "Song of Long Hatred" is very different from history, it is not a historical tragedy, but a love tragedy. The love scene depicted by Li and Yang in "Song of Long Hatred" is very different from the historical scenes that they actually existed in real life in the past[12]。 From a historical point of view, this poem will inevitably be misinterpreted, and we can only start from the characters of Li and Yang portrayed in "Song of Long Hatred", that is, from the specific storyline.

Bai Juyi compiled "Song of Long Hatred" into a collection of poems, and chanted its theme in the preface: "A long hatred has a style, and ten Qin chants are close to the right sound." This is a gesture to the style and meaning of "Song of Long Hatred". Bai Juyi proposed that the creation of "Song of Long Hatred" is not in "Zhengsheng", but in "style". The righteous, Yaya; "Zhengsheng", Yashiya; "Ten Qin Yin Nearly Zhengsheng" is the reason for the abolition of the king's government[13]。 And the wind, the wind moves the insects, and the words rule all things; "Style" is the sound of the terroir, and words and things and human feelings are also exciting. Because literature has the word "coquettish", the wind and the coquettish are intertextual, so "amorous" is actually coquettish, and the wind and mulberry are also under the water. In short, a long-hated "style" is really a sassy feeling, and it is also a satirical feeling. However, Bai Juyi also said, "There is no sound in the world, and pleasant is entertainment." There is no positive color in the world, and pleasing to the eye is beautiful", which opens the door to singing for the legitimacy of the entertainment of the ears, eyes, and colors[14]。 "Song of Long Hatred" is pleasing to the

ears and eyes, heart-shaken, and emotional, which is the true meaning of the word "style". Therefore, even if it is ironic and stabbing the world, from the perspective of the effect, it is also in the tail swing. In the distant memory of that stormy dynasty, the courtesans in Chang'an City boasted that "I can recite the White Bachelor's "Song of Long Hatred", and their value doubled.

First, the first half of "Song of Long Hatred" has the interest of "guiding luxury and prostitution", and the second half is the thoughts of folk legends of men and women. Originally, the son was silent; But "Song of Long Hatred" prefers to invite the Taoist priest to do things. This is not orthodox, and it is all based on the ideas and beliefs of the market to find a way out of pleasure. Emperor Tang Ming and Yang Guifei were transformed into infatuated men and women who flew like wings and became united forever, so they entered the scene and became a joke. "Song of Long Hatred" is not written about the Li Longji in history, but about the Tang Ming Emperor who is full of civic interest. What is written in the song is not a good emperor who sits alone in a high hall and follows rules and moral standards; is written as the story of the red men and green women in the hotel teahouse and the temple fair, a bad man who only cares about his own sexuality, acts arbitrarily, and does not follow the rules. This is a good thing for literature, no bad people are not literature, no lewd run is not rap literature. If you don't deviate from the social and political personality of the king of a country, and don't escape the moral image of the supreme of all nations, then Li Longji, who has a high and stern face, is not a cute and pitiful Tang Ming Emperor who is resentful and melancholy, and an unstoppable impatient Tang Ming Emperor like a disciple; There is no such thing as a close and favorite part of the public; Li Yang's love story will not contain a fresh atmosphere of the folk, that is, it will not float out of the complex atmosphere of individual fate, and it will not have the habit of free temperament[15]。 Why has "Song of Long Roots" survived to this day? One of the most important factors is that it satisfies the emotional needs of ordinary people to spend a full moon. Where is "Long Root Song" interesting and readable? It is to write the interest of the citizens and scratch the itch of the citizens' interests. As one person put it, it "contains the ideal of the city's dwellers, imagining the feudal emperor as an ordinary person like himself, a human infatuation and love with love, distress, mistakes, and shortcomings, which is no different from the protagonist of an ordinary love story." ”

Second, Li Yang's love is a tragedy, and the tragedy includes the tragedy of fate, the tragedy of (individual) character, and the tragedy of society. What is the cause of the tragedy of the beautiful Yang Yuhuan? The reason is that the creation plays tricks on people, giving her a too beautiful and coquettish appearance. "What is beautiful is evil." He is not guilty, but he is guilty. Women are guilty, and beauties (stunners) are even more guilty. "It's hard to give up on being naturally beautiful", it's hard to think about whether you're beautiful or not; It's even more difficult to be beautiful and not to attract jealousy. In addition to the psychological envy of the world, there are also social reasons for her tragic love. Because her love is not just a personal love, his love is criss-crossed and implicates the interests of too many people. There are harem concubines, civil ministers and military generals, and there are inextricably linked people who can't be seen or touched. Li Bai, such a self-respecting and romantic poet, is also jealous of her beauty. Famous flowers love the country, and the king looks at it with a smile. Explain the infinite hatred of the spring breeze, and the agarwood pavilion is leaning on the north of the gan. What's more, she lives in the feudal patriarchal lineage, and a person who has attained Taoism and

a chicken dog ascends to heaven. Yang Yuhuan was favored, and Li Longji sealed the Yang family. On the contrary, the Yang family miscalculated, and of course Yang Yuhuan on a jade-colored chessboard was also affected. The blood society is the sum of the relationship between many people and one person, and if you are favored, your relatives have a network of gold and silver threads, and if you fall out of favor, this net is burned as a grass snake gray line. A gust of wind came, and Yang Yuhuan died with a luxurious peony and the Yang family. Love in feudal times was never a one-person affair. What's more, Yang Yuhuan's love is too "high in the palace" and too admired by everyone, which caused her love to collapse too violently, too heavy and too heavy. Yang Yuhuan's love is floating in the sky, but getting too close to the sun will cause the danger of burning. The beauty's skin is like clotted fat, too tender and delicate, neither can withstand the rain and wind of the rumors at the palace gate, nor can she stand the sun and the sun shines brightly. Yang Yuhuan's death was suffocated by the hypoxic situation at the peak[16]。

On the side of the mountain top, there is a long-hated tree on the slope of Ma Wei, and a blood-colored peony hangs alone on the branches. "Song of Long Hatred" is not so much about love itself, but about something other than love. Love needs an insurance policy, Yang Yu is bad except for Tang Minghuang's favoritism, her love does not have a more powerful guarantee, she has no heirs, and she can't pass on the ancestry, so don't talk about sealing his wife and son, let alone others. For example, the glory of the ancestors, such as the descendants of all generations, such as the continuous flow, these feudal patriarchal systems attached to the extravagant hope of love and marriage, she can't get a straw. That is, a generation of emperors gave Yang Yuhuan a moment of love, but a feudal system will not protect her destiny in life.

Third, Yang Yuhuan is painful as an individual, but for all sentient beings, it is happy to have a Yang Yuhuan in history. If there is no Yang Yuhuan, the literati will be lonely, the study will be dim, the market will have a lot less talking points, there will be fewer associations between men and women, the legends of the world will lose a color, and the world will be lonely. Yang Yuhuan's death was lonely, and her death was lively. Because the world has Yang Yuhuan, there is more sweet sleep shade under the eaves of the market, there is an extra bowl of wine on the square table, there is a beautiful look up to the moon through the window in the middle of the night, there is more excitement of drinking tea and listening to comments in the bookstore, there is a scene of betting and vows under the flower wall, there is an extra layer of graceful spring colors of red men and green women on the cheeks and necks in the green, and there is a rich story painting wall in the literary hall. Yang Yuhuan's personal pain has a common aesthetic value in the world. It provides a trembling horror for the men and women in the rolling red dust for thousands of years, a lingering vow, and the yin and yang are separated but can linger and comfort each other, as well as the infinite sustenance for the next life and the afterlife[17]。 If there was no Yang Yuhuan, there would be more than half of the books on the library shelves; More than half of teachers and literary theorists will be unemployed. Yang Yuhuan is not only for reading and seeing, but only for shallow imagination and association. Yang Yuhuan also provides a distance between love and desire that can be analyzed, clarifying the chaos of love, extracting beauty from the distance, which can be materialized into essays and writings. Yang Yuhuan is still here to write for scholars and support their families. This is the resource provided by the tragic beauty, the dialectic of the transformation of resources from spiritual to material. Writer Ding Ling said: There has never been a talk about love only

about love, love always reflects and attaches to things other than love, and Yang Yuhuan also has to bear things other than love. is not only conceptual consumption, but also material consumption, that is, it has to bear thousands of mouths attached to Yang Yuhuan to eat her.

Fourth, in addition to aesthetic and economic significance, Yang Yuhuan's fate also provides a negative proof of the social rationality of the modern contract system. In ancient times, Yang Yuhuan became a concubine. Her love has become a resource for the prosperity of the Yang family and even the Yang clan, and she has the family glory of "sisters and brothers are all lies". Because of her, the Yang family has good food, good drink, and fun, as well as a lot of "poor brilliance", and has endless wealth. In the patriarchal society, Yang Guifei is the guarantee of everyone in the Yang family and the entire Yang clan. A Yang Yuhuan is not only the insurance policy and bank account number of the Yang clan, but also the doctoral diploma and officialdom pass of the Yang family. On the contrary, Yang Yuhuan collapsed in an instant, and the insurance policy would become invalid and become a miserable piece of waste paper. Because Yang Yuhuan's love is not a physical contract, and there is no guarantee of the contract society, the insurance policy itself is also unreliable. Yang Yuhuan was nothing more than the emperor's affiliation, and on a whim, Yang Yuhuan became a plaything that Li Longji picked up by chance, a vase, a bird, or a couch on his side. The emperor can afford to take it when he is happy, and he can put it down if he is not happy. The beauties of the emperor are as many as the rooms of the palace, and they are not a scarce resource. He can enter this bedroom and walk into the other. The concubine was nothing more than a piece of furniture in the imperial palace that could talk, sing, and dance. Who would sign a contract with a piece of furniture? The reason why Yang Yuhuan is miserable is that she is not really an independent and individual woman, even if it is just a woman who inherits the lineage. She doesn't seem to be prepared to produce children. Yang Yuhuan was born to be a dish of the emperor, and "once selected on the king's side" was for the emperor to eat. Originally, the mother was more precious than the son, but she didn't have this blessing.

Fifth, Bai Juyi's ass sits high above the feudal palace, the tip of the pen is interesting in the greasy and vulgar shop, and in real life there are groups of concubines in his deep house. He wrote "Song of Long Hatred", which was written very easily, and he lightly touched Yang Yuhuan's death, as light as a cloud of smoke. On the contrary, Bai Juyi wrote about Yang Yuhuan's naturally beautiful posture, the delicate and weak flattering posture, the human posture of the night and the emotional gaze, which was thick and colorful, and the writing was very obscene. Bai Juyi is a vulgar person. "A long hatred has a style". What is style? The ancients had a saying: "The wind, let it go." The wind is tempted by the peony. Feng Menglong said: "I heard that men are greedy for women in the world, and it is called amorous. "Men are greedy for women's love, this is the tone and fun of "Song of Long Hatred". Bai Juyi's famous literary motto "Poetry is written for the time", this "time" is the "time" of the rhyme, the "time" of fashion and interest, and the fashion of the pen is the word "kitsch".[18]。 The love words are elegant, and the words are fun and kitsch. In fact, the sound and color of "Song of Long Hatred" is a low-level market taste. Bai Juyi's low-level interest is also manifested in the "reunion" treatment of death. Unlike "Romeo and Juliet", where the sky collapsed and the jade was burned, the "death" of "Song of Long Hatred" is "reunion" even though it is still alive, it can meet yin and yang, can be passed on by Taoist priests, and can make vows to make an appointment. Yang Yuhuan "gazed at the king with affection, and the sound

and appearance were faint", vowing the happy ending of the Qiqi Magpie Bridge Meeting, giving people a warm tail and smoothing the broken psychology. There is also the "wish to be a winged bird in heaven, and a branch in the earth." With endless tenderness, it is interspersed with the rupture of a life and death story. For thousands of years, a tragic conclusion has not only not moved the soul to mourn, but has become a sweet vow of happiness. It is often said that sadness is sadness, sadness is the emotional level, and sadness is the rational level. "The days are long and the time is endless, and this hatred lasts forever", sad but not sad, not a reflection of love, but a proverb of love, just saying that love is fate and regret, and the stories of men and women trapped in the rolling red dust are always irrational.

Sixth, the reason why love is love is not because of the story, but because of the appeal of the love theme and the appeal of people in love. The love story of "Song of Long Hatred" is pale, and the character of Yang Yuhuan is evergreen. For thousands of years, for the people in the market, Yang Yuhuan can stand on paper, walk out of songs, use it for sympathy, evoke body temperature, have texture, and have the imagination of being touched. And what about the one called "Li Longji"? If it weren't for Yang Yuhuan, I'm afraid that few people in the world would know about Li Longji. There are only three words left of "Li Longji", which is just an imperial symbol; Yang Yuhuan is a fresh and charming living person. She can be transformed into a vivid image of life, living in the deep alleys of the neighborhood, living in the high-rise buildings facing the street, living on the other side of the bridge, and living under the locust tree. Without the plump Yang Yuhuan, without her charm of "natural beauty and hard to give up", what Li Longji is left is nothing but describing the withered tree as "Huang Ai's scattered wind and depression". Li Longji will be unable to log into a poignant legend and be lonely, and will disappear without a trace. Therefore, Li Longji was handed down because of Yang Yuhuan[19]。 No way, this is due to the inherited power of human affection. In fact, not only did Li Longji fall into loneliness after losing Yang Yuhuan, but the world could not do without Yang Yuhuan. If there is no Yang Yuhuan, the world will be lonely to death.

5.2.3 The feelings expressed are beautiful

Bai Juyi has left the story of these two people far away, and has turned into the most sincere description of the world. Each of us has this hope, and feels that if there is such a sincere love in our lives, then there will be no regrets. From a narrative to the final idealized expression, in the end, Bai Juyi just wanted to use the love story of Li and Yang to express the truth of the world, so many people were moved by this poem.

A long-lasting thought. The laughter and laughter left behind in the past, the pond garden that records their love, does not detract from its magnificence in the slightest. The hibiscus is still slim and jade on the clear water spiritual liquid, and the filament wicker is still swaying in the soft breeze and spring. The fresh and beautiful lotus flowers turned into Yang Guifei's flower-like face, and the soft willow leaves turned into Yang Guifei's two thin curved eyebrows. is completely an infatuated son who is loyal to love and abides by true feelings, his thoughts about Yang Guifei have been strong for a long time, and in his place, time is the most incompetent catalyst[20]。

"Jin Que West Chamber, knock on the jade, transfer to the little jade to report the double success", through layers of notifications, the concubine finally reappeared, and she suddenly woke up from the

Jiuhua tent. The surprise finally waited for Xuanzong. "Wandering" is the hesitant expression of the concubine, now it is a different side of the world, the fairy world and the world, why bother to see each other, seeing each other will only make each other more sad. It's too late to dress up, one of the jet-black clouds hangs obliquely on the ears, and the other has a delicate flower crown with a messy hairpin. With affection, he stared at the messenger for a long time, and confided in the bitterness after separation: in Penglai Palace, at the end of the sunrise and the end of the month, year after year, he could not communicate with Xuanzong, even if he looked back at Chang'an and wanted to glance at him from afar, there was smoke and dust and clouds that covered the sky and the sun.

6. Conclusion

According to the above analysis, the author has strong feelings for the love tragedy between Emperor Tang Ming and Yang Guifei. He vividly narrated this famous historical event through the plots of Emperor Tang Minghuang's beauty pageant, pampering beauty and fascinating beauty, killing beauty and mourning beauty, and remembering beauty and mud beauty, and used exquisite and clear language to vividly narrate this famous historical event. Thus, the subjective and objective reasons for the Tang Empire's transformation from governance to chaos and from prosperity to decline were profoundly analyzed; further illustrates that the love between Li and Yang can only start with a comedy and end in tragedy. Through this historical story, I will tell the readers: An emperor who was once known as a wise emperor finally caused trouble because of his addiction to women, gullibility and treachery, waste of state affairs, and extreme desire for luxury. The author regrets that the Ming Emperor has fallen into a faint king, and hopes that future emperors (or playthings who have lost their minds) will take this as a warning and not repeat the mistakes of the past. On the other hand, the author wrote the love between Li and Yang in a singing and crying way: they are sincere and single-minded with each other and never change their hearts. He expressed deep regret and sympathy for their failure to finish well. Thus implying to the reader that such a love is noble, sacred, and worthy of praise.

"Song of Long Hatred" can be a metaphor for love, so as to highlight the theme, which shows the depth of Bai Juyi's thought and superb artistic technique, which is very out of people's reach. As for his glorification of the emperor, it was limited by the times and classes.

References

[1] BIAN Xueying. Masterpiece Appreciation,2024,(21):93-95.

[2] ZHAO Yifei. Journal of Kaifeng Vocational College of Culture and Art,2024,44(02):23-28.)

[3] GAO Xinyi. The emotional connotation of "spring" in "Song of Long Hatred"[J].New Legend,2024,(13):4-6.)

[4] Su Maozhi. Tang Bai Juyi's "Song of Long Hatred"[J].Special Zone Economy,2024,(02):161.)

[5] Teng Hanyang, Wang Xingnan." The Tone Change of "Style": Bai Juyi's Journey Transition and the Theme Transformation of "Song of Long Hatred"[J].East Asian Tang Poetics Research,2023,(02):199-214.)

[6] CHEN Siyu. The homogeneous themes and themes of "Song of Long Hatred" and "Mrs. Li"[J].Journal of Shenyang Institute of Technology(Social Sciences),2023,19(03):14-20.)

[7] YANG Xinzi. Analysis of the dual themes of Bai Juyi's Song of Long Hatred[J].Couplet,2023,29(10):11-13.)

[8] Chen Wenzhong." There are lovers in the world" and "fallen people at the end of the world"——A comparison of the interpretive history of "Song of Long Hatred" and "Pipa Xing"[J].Theoretical Studies in Ancient Literature,2022,(01):278-302.)

[9] Dai Ruilan. Inferior to the Lu family: A brief analysis of the tragedy of the image of the concubine in "The Song of Long Hatred"[J].Comparative Research on Cultural Innovation,2021,5(36):28-31.)

[10] Guo Jie." Journal of Henan University(Social Sciences),2021,61(06):87-93.)

[11] WEI Baohua. Journal of Yueyang Vocational and Technical College,2021,36(05):77-80.)

[12] LIN Jie. On the immortalization plot and the theme of "Long Hatred" in "Song of Long Hatred"[J].Tangdu Academic Journal,2021,37(04):30-36.)

[13] HU Yuanyuan. Journal of Jiujiang University(Social Sciences),2020,39(04):100-104.)

[14] XU Yixin. A brief analysis of the connection between poetry and legend in the Tang Dynasty: A case study of "Song of Long Hatred" and "Song of Long Hatred"[J].Chinese Character Culture,2020,(10):61-62+73.

[15] Cui Chenli. Journal of Lanzhou University of Education,2020,36(03):35-37.)

[16] XU Hean. A "Long Hatred" is all sentimental —— Bai Juyi's "Long Hate Song" theme identification[J].Journal of North University of China(Social Sciences),2020,36(02):80-84.)

[17] LIAO Wen. Exploration of the difference between "The Song of Long Hatred" and "The Song of Long Hatred"[J].Journal of Puyang Vocational and Technical College,2020,33(01):80-83.)

[18] YANG Chenxue. Bai Juyi's "Song of Long Hatred" emotional projection exploration[J].Chinese Character Culture,2019,(24):52+65.

[19] LI Le. Bai Juyi's "Song of Long Hatred" multiple meanings[J].Famous Masterpieces,2019,(11):120-121.

[20] GAO Dongmei. A multi-angle exploration of the theme of "Song of Long Hatred"[J].Middle School Chinese,2019,(24):88-90.)

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Discourse Expression of Gender Differences in English Language ——Taking *legally blonde* as an Example

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Abstract: In linguistic academic research, gender differences are often reflected in discourse patterns, vocabulary selection, and intonation. This paper focuses on the discourse expression of gender differences in the English language, using the film Legally Blonde as a specific case study. The dialogues of different gender roles in Legally Blonde exhibit typical characteristics. Through the analysis of this film, it is found that male discourse tends to be more direct, concise, and authoritative, while female discourse contains more emotional nuances and euphemistic vocabulary. From a pragmatic perspective, this difference effectively reflects societal role expectations for different genders. Through an in-depth study of the character dialogues in the film, this research helps reveal the forms of gender differences in English discourse expression, providing new perspectives for better understanding the relationship between gender and language in cross-cultural communication and language learning, as well as offering a reference for eliminating language biases caused by gender.

Keywords: English language; Gender differences; Pragmatics; Discourse expression; *Legally Blonde*.

I. Introduction

(I) Research Background

1.1.1 The Importance of Studying Gender Differences in the English Language

From a linguistic perspective, examining gender differences enriches academic research by providing diverse angles for inquiry. For example, at the semantic level, studies have shown that the same word can carry completely different meanings depending on gender. The term "bossy," when applied to women, often carries negative connotations of being domineering, whereas similar behavior in men might be described as "assertive." This phenomenon prompts semanticists to re-examine the relationship between lexical semantics and social factors such as gender, thereby enriching semantic theory. Gender is also a significant factor contributing to variations in the English language. Differences between genders may manifest in phonetics, vocabulary, syntax, and other linguistic aspects. For

instance, women, especially those specializing in language studies, tend to use standard pronunciation more frequently, as their language abilities develop earlier, giving them an advantage in linguistic proficiency. Men, on the other hand, may exhibit more diverse accents, including regional variations, due to less emphasis on standardized pronunciation. Research into gender-related linguistic variations helps comprehensively understand the diversity of the English language, recognizing that language is not a monolithic system but a rich tapestry of variations influenced by multiple social factors. From a socio-cultural perspective, studying gender differences helps uncover hidden gender power structures in society. For example, men have traditionally held dominant social positions, and this power dynamic is reflected in language use. A clear illustration is the difference in apology strategies: women tend to use more euphemistic language to express politeness and preserve others' feelings and dignity (face), whereas men are less likely to apologize, as apologizing might be perceived as undermining their dignity. Even when apologizing, men tend to use more formal and appropriate language. In contrast, women are more adept at employing apology strategies to maintain relationships and are more likely to accept apologies. [2]

1.1.2 Reasons for Selecting *Legally Blonde* as a Case Study

From the context of feminist development, women's demands for social status transformation have become increasingly prominent since the 1990s. Although progress has been made in education and employment, women still face numerous restrictions and stereotypes in traditional views. At the time of the film's setting, the United States was entrenched in a male-dominated societal structure. [3] In this context, male lawyers were commonly seen dominating courtrooms, a scenario audiences had grown accustomed to, as professions like law were traditionally viewed as male-dominated fields. This perception is reflected in the film through the prejudice encountered by Elle Woods upon entering Harvard Law School. Historically, women have been marginalized, often relegated to roles as dependents or even "appendages" of men. [4] The phrase "men rule outside, women rule inside" encapsulates this dynamic. However, the protagonist Elle Woods defies societal expectations, symbolizing women's resistance to traditional gender roles in real life and their pursuit of self-worth and social status. From the perspective of female self-awareness, an increasing number of women are no longer content with roles such as "housewives" or subordinate partners. Elle evolves from a fashion-obsessed young woman into a determined and accomplished legal professional, reflecting this trend of self-awareness. In fact, the film's backdrop coincides with the aftermath of the Third-Wave Feminist Movement in the United States, which significantly improved women's status in education, politics, and other domains. Women gradually gained recognition and respect, achieving milestones such as suffrage and increased political representation. For instance, the number of women in the U.S. Congress rose from 10 in 1960 to 16 in 1979, including 16 Black women. [5]

(II) Research Objectives and Significance

1.2.1 Research Objectives

1.To deeply analyze the specific manifestations of gender differences in English discourse expression through a detailed examination of dialogues in *Legally Blonde*. This includes exploring vocabulary choices, syntactic structures, intonation, and attitudinal expressions to provide vivid case studies and robust data support for gender difference research in the English language.
2.To investigate the factors influencing gender differences in discourse expression by contextualizing the film's social background, cultural values, and character relationships. This involves analyzing how societal role expectations, cultural traditions, and specific scenarios shape gendered language use, thereby enhancing understanding of the interplay between language, society, and culture.
3.To offer insights for promoting effective cross-gender communication. By revealing gender differences in English language use through the film, this study aims to foster awareness of gendered communication styles, reduce misunderstandings, and improve the quality and efficiency of cross-gender interactions.

1.2.2 Research Significance

1.Enhancing Cross-Cultural Communication: Understanding gender differences in English across cultural contexts helps communicators better interpret language behaviors and intentions, minimizing conflicts arising from cultural and gender disparities. This study provides concrete knowledge about gendered language differences, improving the quality and success of cross-cultural communication.
2.Promoting Gender Equality: By analyzing how gendered discourse in the film reflects societal realities, this research draws attention to gender inequality and challenges traditional stereotypes. It advocates for respect and understanding of diverse linguistic expressions across genders, contributing to theoretical and practical advancements in gender equality.
3.Informing Language Education: Recognizing that language is shaped by social factors such as class, status, and gender, this study encourages educators to adopt personalized teaching strategies. For example, tailoring vocabulary and speaking exercises to address gender-specific learning needs can enhance pedagogical effectiveness while fostering students' awareness of cross-gender communication.

(III) Theoretical Framework

This study is grounded in **sociolinguistics** and **pragmatics**, integrated with **gender studies** and **Critical Discourse Analysis (CDA)**. This multi-layered theoretical framework systematically elucidates the mechanisms of gendered discourse expression in English and its socio-cultural roots.

1.3.1.Sociolinguistic Perspective: Gender and Power Theory

1.Lakoff's "Women's Language Hypothesis":
Robin Lakoff (1975) posited that women's language often exhibits "powerless" features, such as euphemisms, interrogative intonation, emotional modifiers (e.g., "maybe," "perhaps"), and avoidance of direct commands (e.g., "Could you help me?" instead of "Help me"). These features are seen as reflections of women's subordinate status in societal power structures. In this study, male characters'

use of direct statements and professional terminology contrasts with Lakoff's theory, revealing how men reinforce authority through linguistic monopolization in legal professions. [9]

2.O'Barr & Atkins' "Power and Language Style":

O'Barr and Atkins (1980) found in courtroom studies that language style differences are not solely gender-determined but closely tied to **social power**. For instance, women's use of "powerless language" may stem from occupational status rather than inherent gender traits. This study examines whether Elle's "inquisitive communication" in *Legally Blonde* arises from her novice lawyer status (power disadvantage) rather than gender alone. [10]

1.3.2 Pragmatic Perspective: Face Theory and Communication Strategies

Brown and Levinson's **Face Theory** (1987) provides a critical framework for analyzing gendered language strategies in legal contexts. [11] The theory posits that individuals seek to maintain "positive face" (desire for approval) and "negative face" (desire for autonomy). In professional settings like courtroom debates, male characters employ direct strategies that threaten the hearer's face (e.g., assertions: "You must strictly follow the rules of evidence") to assert authority. In contrast, female characters like Elle use consultative questions (e.g., "Could you first tell me the main points?"), balancing professional discourse with interpersonal harmony through positive face strategies.

1.3.3 Gender Performativity Theory

Judith Butler's **Gender Performativity Theory** (1990) offers a critical lens for understanding the dynamic relationship between language and gender. [12] Butler argues that gender is not an innate biological trait but a social role constructed through repeated linguistic and behavioral "performances." This theory informs our analysis in two ways:

1.Language as a Constructive Force: The monopolization of legal terminology by male characters exemplifies Butler's "normative performativity," reinforcing professional authority through linguistic repetition.

2.Subversive Potential of Discourse: Elle's "consultative questioning" constitutes "subversive performativity," blending emotional expression with professional jargon to destabilize fixed gender boundaries.

II. Research Methodology

(I) Corpus Collection and Analysis

2.1.1 Corpus Selection Criteria

This study extracts dialogues from *Legally Blonde* based on three principles:

1.Scenario Diversity: Covering professional (e.g., courtroom debates, classroom discussions) and informal contexts (e.g., social gatherings, daily conversations).

2.Salient Gender Differences: Prioritizing scenes with pronounced gendered language contrasts, such as male characters' logical assertions versus female characters' emotion-laden expressions.

3.Role Representativeness: Ensuring balanced inclusion of dialogues from major male and female characters (e.g., Elle, Warner, professors).

2.1.2.Corpus Extraction Process

1.Scene Identification: Repeated viewings of the film to mark scenes meeting the above criteria, noting timestamps, participants, and themes.

2.Dialogue Transcription: Verbatim transcription of selected scenes, preserving paralinguistic features (e.g., fillers, pauses).

2.1.3 Corpus Annotation and Organization

1.Scenario Classification: Tagging dialogues by scene type (e.g., courtroom, classroom) and speaker gender.

2.Linguistic Feature Annotation:

Lexical Level: Underlining emotional terms (e.g., "amazing"), bracketing professional jargon (e.g., "hearsay evidence rule").

Syntactic Level: Labeling sentence structures (S-simple, C-compound, CX-complex).

Pragmatic Level: Noting face strategies (e.g., "consultative question," "direct assertion").

3.Quality Control: Cross-verifying transcriptions and removing irrelevant content.

Note: As a theoretical analytical article, this study focuses on qualitative interpretation of linguistic phenomena rather than quantitative data analysis.

III. Case Analysis

(I) Dialogue Analysis

3.1.1 Differences in Professional Terminology Usage

Scene 1: Classroom discussion of a legal case

Male Character: "According to the theory of criminal negligence in criminal law, the defendant's behavior has clearly constituted a negligent crime... The legal concepts involved here are quite clear. Factors like 'subjective fault' and 'causality between behavior and result' are key."

Elle Woods: "Well, I know the concept of criminal negligence, but I think we also need to consider specific circumstances, like the defendant's mental state... I'm a little confused about determining 'subjective fault' here."

Scene 2: Internship discussion with a mentor

Male Mentor: “The key lies in the admissibility of evidence... You must study the relevant legal provisions.”

Elle Woods: “Mentor, I don’t quite understand the ‘hearsay evidence rule.’ Could you first explain its definition?”

Analysis:

Male characters demonstrate fluency in legal terminology (e.g., “criminal negligence,” “admissibility of evidence”), reflecting authoritative command of professional knowledge.

- Female characters contextualize terminology within practical scenarios, adopting a cautious, detail-oriented approach.

From a performativity lens, male terminology monopolization embodies O'Barr's “power language” and Butler's “normative performativity.” Elle's consultative questions subvert gendered norms through “disruptive performativity.”

3.1.2.Differences in Emotional Vocabulary

Frequency and Depth: Female dialogues feature abundant emotional terms (e.g., “amazing,” “accomplished”), while male dialogues prioritize factual statements (e.g., Warner's focus on career goals).

Expressive Styles: Women articulate nuanced emotions (e.g., Elle's “I feel so accomplished!”), whereas men use generalized expressions (e.g., “hope for a good future”).

(II) Communication Styles

3.2.1 Female Communication Style

Relational Focus: Women prioritize emotional connection and shared experiences, as seen in Elle's heartfelt conversations with friends.

Inquisitive Approach: Women frequently employ questions to seek understanding, reflecting Tannen's “rapport-talk” and collaborative problem-solving.

3.2.2 Male Communication Style

Instrumental Focus: Men emphasize logic, efficiency, and goal-oriented discourse, aligning with Tannen's “report-talk.”

Direct Assertions: Male characters dominate discussions through declarative statements (e.g., professors’ lectures), reinforcing authority.

IV. Factors Influencing Gendered Discourse in *Legally Blonde*

(I) Social Roles and Expectations

4.1.1 Gendered Role Allocation

Historically, gender-based labor divisions positioned men as dominant and women as subordinate. Male characters ' direct, authoritative language in legal settings (e.g., courtroom debates) reinforces professional authority, while female characters initially face dismissals of their capabilities (e.g., Elle being labeled a "Malibu Barbie").

4.1.2 Divergent Social Expectations

- **Men**: Expected to excel in careers, using logical, persuasive language to assert competence.
- **Women**: Pressured to prioritize family roles, as seen in Elle's initial motivation to win back her ex-boyfriend.

(II) Cultural Context

4.2.1 Gender Equality Ideals

Subverting Stereotypes: Elle's evolution from a "bimbo" stereotype to a successful lawyer challenges traditional gender roles, symbolizing women's capacity to thrive in male-dominated fields.
Female Solidarity: The film emphasizes women's mutual support (e.g., Elle's friendship with Vivian), countering narratives of female rivalry.

V. Socio-Cultural Significance of Gendered Discourse in *Legally Blonde*

(I).Reflection and Challenge of Gender Equality

The film mirrors real-world gender inequalities (e.g., male dominance in legal discourse) while subverting norms through Elle's hybrid language style (emotional + professional). Her pink-suited courtroom confidence exemplifies how women can redefine professional spaces.

(I) Advocacy for Social Change

Education: Integrate gender equality education using media analysis.
Media: Promote egalitarian gender portrayals in films.
Social Interaction: Encourage respectful, inclusive communication across genders.

VI. Conclusion

(I).Key Findings

1. **Lexical Level**: Women's emotionally rich vocabulary reflects societal expectations but also showcases linguistic versatility.
2. **Syntactic Level**: Women's use of questions and exclamations challenges power imbalances, while men's declarative sentences reinforce authority.

3. **Intonational Level**: Women's dynamic intonation breaks stereotypes of passivity.

(II) Future Research Directions

1. **Cross-Genre Analysis**: Explore gendered discourse in diverse film genres (e.g., action, sci-fi).
2. **Cross-Cultural Comparisons**: Contrast gendered language in Western and Eastern films.
3. **Applied Studies**: Design gender-sensitive curricula and workplace training programs.

References

[1] Butler J. Gender Trouble: Feminism and the Subversion of Identity[M]. New York, London: Routledge, 1990.

[2] Chang Tian. An Exploration of the Relationship Between Language and Gender [J]. Rural Consultants, 2020, (03): 197.

[3] Cheng Yaping. The Narrative Logic of American Feminist Films [J]. *Film Literature*, 2017, (24): 33-34.

[4] Editorial Department. Don’t Be Bound by Gender Stereotypes [J]. Shanghai Education, 2016, (20): 1.

[5] Feng Li. An Analysis of Elizabeth's Feminist Consciousness in Pride and Prejudice [J]. Overseas English, 2024(3): 202-204.

[6] Han Jinhai. Gender Differences in Language [J]. Comparative Studies of Cultural Innovation, 2022, 6 (08): 26-29.

[7] Li Jinchi. The Enlightenment and Impact of Sociolinguistics on English Language Teaching [J]. Modern English, 2020, (24): 93-95.

[8] Li Xin. The Development and Impact of Post-War American Feminist Movements [J]. Youthful Years, 2019, (09): 232.

[9] Li Yinhe. Feminism[M]. Jinan: Shandong People's Publishing House, 2005: 15–63.

[10] Lin Na. The Embodiment of Feminism in the Film Legally Blonde [J]. Film Literature, 2014, (13): 102-103.

[11] Liu Weihong. A Brief Analysis of Gender Cultural Differences in Cross-Cultural Communication [J]. Campus English, 2019, (07): 232.

[12] Lü Changteng. Rethinking Women's Rights from a Gender Perspective [J]. Taste·Classics, 2023, (23): 37-40.

[13] O'Barr W, Atkins BK. “Women's Language” or “Powerless Language” [C]// Language, Communication and Education.

[14] Talbot, M. (2004). Language and Gender: An Introduction (Translated by Ai Xiaoming, Tang Hongmei, and Ke Qianting). Central China Normal University Press.

[15] Tannen D. You Just Don’t Understand: Women and Men in Conversation[M]. Shanghai: Shanghai Translation Publishing House

[16] Wang Shaoping, Hu Jialin. A Utopian Interpretation of Female Community in Amy Tan's The Valley of Amazement [J]. Straits Humanities Journal, 2022, 2(4): 48-55.

[17] Wang Yongliang. Theoretical Foundations and Corpus Collection Methods in Experimental Pragmatics [J]. Literature Education (I), 2015, (03): 117-119.

[18] Wang Yuxiao. Euphemisms from the Perspective of Face Theory [J]. Journal of Anyang Normal University, 2011(4):69-71.

[19] Xu Fang. A Review of Gender Language Studies [C]// Proceedings of the 11th National Academic Symposium of the China Association for Comparative Studies of English and Chinese. 2014:168.

[20] Zhang Jingjie. The Historical Path of Gender Communication Studies in the United States [J]. Modern Communication (Journal of Communication University of China), 2022, 44(11): 46-56. DOI:10.19997/j.cnki.xdcb.2022.11.019.

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A Synergistic Orientation Inquiry into Smart Teaching Feedback and High Quality Development of Teachers' Digital Literacy

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Abstracts: Focusing on the core direction of China's high-quality development of intelligent teaching and learning, and taking the change driven by the vertical large model of education as a breakthrough, we deeply analyse the key constants and essential attributes in the process of digitalisation of education. It reveals the heterogeneous impact of shallow and deep learning characteristics on learning concepts and learning effectiveness, and systematically clarifies the complex interaction mechanisms of learning feedback, methods, concepts and contexts in enhancing learning effectiveness. These findings not only provide solid theoretical support for the transformation of China's digital education, but also provide an innovative practical path for building a high-quality and sustainable education development model, which further empowers the effective implementation of the national high-level education innovation system and talent development strategy.

Keywords: 20th Plenary Session; High Quality Development; Smart Teaching and Learning; Vertical Grand Model of Education; Hierarchical Learning

Introductory

The traditional model of education has been heavily influenced by the theory and practice of quality management, which usually measures the quality of education by setting "high standards" as the guiding strategy for high-quality development of education. However, over-emphasis on "high standards" has led to the limitation of educational activities to a universal standardised framework, which has restricted the innovative vitality and autonomous development capacity of education, and it is urgent to re-examine the concept of "high standards" education in order to explore the key elements and internal logic of the development of high quality in education. There is an urgent need to review the concept of "high standard" education in order to find out the key elements of high-quality development of education and the inner logic of realisation[1] . At the same time, the new round of scientific and

technological revolution and industrial change are accelerating the all-round penetration of digital technology in society, making it a key driving force to profoundly change the way of thinking, organisational structure and mode of operation of society. The data-driven economic and social development pattern is gradually taking shape, and the digital transformation of the education sector and the exploration of smart education have also become an inevitable trend of new technological progress and productivity leap. This transformation has an important fundamental, pioneering and overall role in China's modernisation process, and as an important part of the construction of "Digital China", it is redefining the connotation and practice path of education[2] .

Under the macro pattern of global scientific and technological change and industrial upgrading, education digitalisation has become an important strategic pillar for driving education innovation and enhancing education quality and equity. The Party Central Committee and the State Council attach great importance to the promotion of education digitisation, and the report of the 20th Party Congress proposed for the first time to "promote the digitisation of education, and build a learning society and a learning country with lifelong learning for all people"[3] . In 2023, General Secretary Xi Jinping further pointed out in the Fifth Collective Learning of the Political Bureau of the Communist Party of China (CPC) Central Committee that the digitisation of education is a strategic breakthrough for China to explore a new track of education development and shape a new advantage in education. new track of education development and a strategic breakthrough for shaping new advantages in education. This high level of leadership not only promotes the structural upgrading of the education system, but also inspires educational entities at all levels to innovate their educational concepts and teaching models under digital conditions, providing unprecedented opportunities for achieving fair and high-quality development of education.[4] . In recent years, the Ministry of Education, upholding the concept of "government-led, school-led, social participation", has actively promoted the construction of an integrated system of "building, using, learning and managing" online education resources. The rapid popularity of catechism and online education is changing the way students learn, teachers' teaching methods, school management models and the overall shape of education, opening up a broad space for the development of high quality higher education and future educational innovation. Based on this, the higher education sector urgently needs to build a new type of "smart+" education ecosystem in terms of the concept of educating people, the mode of running schools, the teaching method, the learning paradigm and the evaluation method, in order to cope with the demand for deep-seated changes brought about by the digitisation of education.

1.Design and Re-optimisation of Educational Feedback Mechanisms

Based on the strategy of "integration of education, intelligence and talent training" proposed by the Third Plenary Session of the 20th Central Committee of the Communist Party of China (CPC), we will discuss in depth the key role of intelligent teaching in optimising the design of teaching and innovative development paths. Through educational feedback, it promotes the improvement of teaching quality and the optimal allocation of resources, thus cultivating a high-quality teaching force and providing global guidance for the digital transformation of the education system. From the perspective of smart teaching, the reconstruction path of digital teaching is systematically analysed, focusing on the

synergistic effects of learning concepts, feedback mechanisms, teacher development and digital literacy. The study shows that deep learning not only improves knowledge acquisition, but also significantly enhances critical thinking and comprehensive literacy, which provides forward-looking guidance for curriculum design; at the same time, it reveals the complex interaction between learning feedback, teaching methods, learning concepts and contexts, which highlights the key role of effective feedback in deep learning. Diversified teaching methods are better suited to different learning needs, and positive learning concepts stimulate students' intrinsic motivation, enabling teachers to flexibly take on the roles of learning guides, designers and feedback supporters in intelligent teaching.

1.1 Shaping of Deep and Shallow Learning Contexts

Under the framework of smart teaching, optimising the design of deep and shallow learning contexts has become a key proposition to enhance students' learning experience and effectiveness. Shallow learning contexts are usually based on mechanical memorisation and repetitive exercises, which can improve memory effects in the short term, but when faced with complex cognitive tasks, they often lack the motivation to stimulate students' deeper learning motivation, which can easily lead to burnout and a sense of detachment. The limitations of such contexts in terms of content and format make it difficult to support students' active adaptation and flexible transfer in higher-order tasks, making it difficult to effectively internalise what they have learnt into comprehensive abilities to cope with dynamic situations, and thus weakening their potential for cognitive expansion[5] . In contrast, smart teaching-oriented deep learning contexts emphasise the stimulation of students' subjectivity and sense of self-knowledge, and through the construction of diversified learning paths, students are motivated to choose appropriate learning contents and methods according to their individual needs, so as to achieve deep understanding and promote the long-term retention of knowledge[6] . In this context, students' intrinsic motivation is stimulated, and they gradually form self-driven learning habits. Through cooperative learning, project-based learning and other diversified forms, Smart Teaching provides students with personalised growth paths and significantly broadens their learning experience, which not only realises the education concept of tailoring teaching to students' abilities, but also allows students to flexibly adjust their strategies and strengthen their adaptive abilities in a variety of contexts. Students develop the core qualities of critical thinking, communication skills and complex problem solving through group work, independent research and project investigation, and gradually build up comprehensive academic competence.

The design of deep learning contexts goes beyond the single goal of traditional knowledge transfer to enable students to cope with future uncertainties and complex situations through the cultivation of multidimensional competencies. In this process, the efficient design of the feedback mechanism is especially critical. Personalised feedback helps students identify their cognitive blind spots and optimise their learning strategies through reflection. Fine-tuned feedback not only enhances learning outcomes, but also promotes the development of critical thinking and higher-order cognitive skills[7] . The feedback-driven learning model of Smart Teaching and Learning guides students to self-assessment and strategy optimisation, helping them to adapt to complex learning situations while building up their

confidence and ability to learn independently, thus laying a solid foundation for their future academic and professional careers.

1.2 The Deeper Utility of Learning Feedback

In shallow learning situations, feedback is often limited to a simple judgement of the correctness of the answer, focusing mainly on the completion of the task and failing to explore in depth the students' understanding of knowledge. This unidimensional feedback model cannot effectively support knowledge transfer or in-depth internalisation, and often results in students remaining in the shallow cognitive stage[8] . In the absence of systematic and inspirational feedback, students tend to repeat their mistakes or avoid them rather than optimise their learning strategies through reflection, thus further limiting the development of independent learning[9] . In contrast, the deep feedback advocated by Smart Teaching sees feedback as the core mechanism driving students' self-assessment and reflection, and aims to help students deepen their understanding through comprehensive support. This feedback mechanism not only focuses on learning outcomes, but also emphasises all-round support for the learning process. Through accurate identification of knowledge blind spots and inspirational guidance, the multi-dimensional feedback mechanism of Smart Teaching can help students re-examine the knowledge structure and gain new cognitive perspectives, thus effectively promoting the in-depth internalisation and transfer of knowledge.

Structured and precise feedback guides students' reflection and strategy adjustment through heuristic question design and in-depth analysis, thus gradually enhancing their resilience and cognitive flexibility. Specific and timely feedback not only enhances learning outcomes, but also boosts students' confidence and their engagement and self-efficacy in complex tasks. In the framework of deep learning, feedback has evolved from a traditional "assessment tool" to a "support mechanism" throughout the learning process. Feedback in Smart Teaching and Learning optimises learning strategies and develops students' critical thinking, exploratory perspectives, and self-directed learning skills to support their ability to cope with complex problems and lifelong learning needs. This feedback-driven model ensures that students are equipped with a solid foundation of cognitive depth and breadth of knowledge and are motivated to continue learning.

In addition, under the wave of digital transformation, the efficiency of the feedback mechanism is closely related to the improvement of teachers' digital literacy. Teachers' roles in smart teaching have gone beyond mere knowledge transmitters to become learning guides, resource designers and feedback coordinators. The improvement of teachers' digital literacy provides important support for the optimisation of feedback mechanisms and personalised learning. For example, through the flexible use of data analysis tools, teachers can adjust their feedback strategies in real time to ensure that they are highly compatible with individual student needs, thus further optimising learning outcomes. The effectiveness of deep feedback is reflected in its ability to stimulate students' intrinsic motivation and cultivate their strategic flexibility. Through the use of diversified teaching resources, teachers are able to construct multi-dimensional contexts to suit the cognitive characteristics and developmental needs of different students. This feedback model not only helps students consolidate their knowledge, but also

enhances their ability to reflect, explore, and solve complex problems, ultimately laying a solid foundation for their future academic growth and career development.

In the paradigm transformation of smart teaching, the refined reconstruction of the feedback mechanism and the comprehensive improvement of teachers' digital literacy together constitute the key support for the digitalisation of education. This double-wheel drive synergy not only promotes the dynamic improvement of teaching quality, but also opens up innovative practical paths for students to adapt to the complex and diverse challenges of the future. In a technology-driven education ecosystem, teachers need to combine digital tools with deep feedback design to ensure a dynamic balance between the essence of education and technological empowerment, thus promoting the realisation of high-quality development in education.

2.Teacher Professional Development and Digital Literacy

Along with the acceleration of the global digitalisation of education, the role and competence needs of teachers are undergoing a profound transformation. As the key implementers of smart teaching, teachers not only need to be skilled in the use of digital technology, but also need to act as innovators of digital resources and drivers of pedagogical change. High-quality improvement of digital literacy directly determines the ability of teachers to achieve in-depth innovation of teaching models in a dynamic educational environment, and at the same time relates to the satisfaction of diversified educational needs and optimisation of teaching quality. It provides a continuous driving force for the overall transformation of the education system, promoting the diversification of teaching methods and the innovation and upgrading of education models.

2.1 The Meaning, Importance and Impact of Digital Literacy

As the process of education informatisation advances, teachers' digital literacy has moved from a single skill to a multi-dimensional competency system. Digital literacy consists of three key dimensions, namely, technical competence, information literacy and digital creativity, covering the whole process from the proficient use of educational technology to the critical analysis of information resources and the enhancement of classroom interactivity and creativity through digital tools[10] .

Skillful use of technology is the foundation of digital literacy, requiring teachers to be proficient in tools such as online teaching platforms, classroom management systems and data analysis. Through these tools, teachers can optimise the organisation of teaching and allocation of resources, and monitor students' learning performance in real time, thus providing scientific support for the development of personalised teaching strategies. The level of technological competence directly determines the ability of teachers to promote the effectiveness of smart teaching in the digital environment[11] .

As the core dimension of digital literacy, information literacy emphasises teachers' ability to acquire, filter, analyse and integrate information resources. In the digital era of information overload, teachers not only need to be the screeners of high-quality information, but also need to guide students to develop information discernment and critical thinking. By constructing in-depth learning contexts, information literacy empowers teachers to design more inspiring and challenging teaching programmes to help students achieve deeper learning in diverse information environments[12] .

Digital creativity represents an advanced form of digital literacy, which is reflected in teachers'

ability to design innovative teaching and learning activities through digital resources, enhance the attractiveness of the curriculum, and stimulate students' creative thinking. Through digital creativity, teachers can not only enhance the interactivity and immersion in the classroom, but also facilitate students' transfer of knowledge and innovation by applying knowledge to complex problem situations[13] . Educational policies around the world generally require teachers to enhance their digital creativity to meet the needs of modernising education. For example, the EU's Digital Education Action Plan (2020) and China's Education Informatisation 2.0 Action Plan both explicitly state the strategic goal of enhancing teachers' digital creativity[14] . The implementation of these policies not only provides institutionalised support for the enhancement of teachers' digital literacy, but also pushes teachers to become a key driving force for education modernisation in the global wave of education digitisation, further consolidating their central position in education transformation.

2.2 The key role of digital literacy in deep learning and feedback mechanisms

In the smart teaching ecology, the improvement of teachers' digital literacy accelerates the leap in teaching technology capabilities, and through the deep coupling of technological tools and teaching objectives, learning environments that support the development of students' independent inquiry and critical thinking can be effectively constructed. The design and implementation of such deep learning contexts provide multi-dimensional support for students' personalised growth and learning effectiveness. Deep learning contexts are different from the mechanical memorisation and repetitive practice of shallow learning, and focus more on students' intrinsic motivation and the flexibility of learning strategies. Teachers create a challenging and inspiring multi-dimensional learning environment for students through innovative digital resource design and integration of teaching methods. Research has shown that when students are able to choose their own resources and tasks within flexible learning pathways, their depth of understanding is significantly increased, and they are more likely to develop long-term memory and critical thinking skills[15] . Through collaborative and project-based learning supported by digital tools, students are able to develop core literacy skills in complex tasks, setting them up for future academic and professional challenges.

Feedback is an important driver of deeper learning, and improved digital literacy of teachers enables this mechanism to be more accurate and adaptable. In traditional teaching, feedback is often limited to a simple assessment of the correctness of answers, which is difficult to support knowledge transfer and learning strategy optimisation. In a smart teaching environment, data-driven feedback accurately identifies students' knowledge shortcomings and guides in-depth reflection through multi-dimensional analysis to promote knowledge internalisation and transfer[16] . Teachers provide immediate and targeted feedback to assist students in identifying learning errors and optimising their cognitive pathways, while developing reflective thinking and self-regulation to enhance learning effectiveness and independent learning ability. This feedback mechanism is used throughout the learning process to guide learners to adjust their strategies and optimise their perceptions, thus enhancing their learning effectiveness and motivation[17] . Under the framework of deep learning, the feedback and reflection mechanism provides strong support for students' growth in complex contexts through personalised design and dynamic adaptation.

The construction of deep learning context and high-quality feedback mechanism provides a solid theoretical foundation and practical support for the application of intelligent feedback technology. With the advancement of educational intelligence, teachers can further optimise the feedback paradigm on the basis of digital literacy, using artificial intelligence and big data analysis to provide personalised support for students with different cognitive characteristics. This feedback paradigm is not only reflected in the application of technical skills and the design of innovative resources, but is also the core driving force for the construction of deep learning contexts and the optimisation of feedback mechanisms[18] . By improving digital literacy, teachers are able to flexibly respond to complex tasks, accurately meet students' diverse needs, and guide students to realise knowledge transfer and thinking innovation through efficient feedback mechanisms in a smart teaching environment[19] .

3.An Innovative Paradigm for Instructional Feedback and Intelligent Strategies

In the intelligent teaching system, teaching feedback, as a key link between teachers, students and the learning process, has transcended the function of one-way transmission of information in traditional education, and transformed into a core driving force to promote the improvement of the quality of teaching and personalised learning changes[20] . With the rapid development of Artificial Intelligence (AI), learning analytics and big data technologies, intelligent feedback is profoundly reshaping the interaction mode in the education field. The transition from static, generalised feedback to dynamic, personalised feedback has given greater precision and adaptability to the instructional design and feedback mechanism, enabling it to respond effectively to the individualised needs of students, while promoting the collaborative development of teachers and students in deep learning environments. The introduction of intelligent feedback marks the paradigm shift of educational practice from traditional "outcome assessment" to "process optimisation", laying the foundation for a comprehensive transformation of teaching and learning activities. In the basic learning stage, intelligent feedback monitors learning behaviours in real time and quickly generates accurate error diagnosis and guidance suggestions to strengthen students' knowledge base. For example, when a student completes an exercise task, the intelligent system can instantly identify his/her cognitive bias and provide specific guidance for error correction. This rapid response feedback mode not only improves students' learning efficiency, but also enhances their motivation and participation in learning, laying a solid foundation for higher-order learning.

In the process of achieving continuous learning goals, intelligent feedback relies on data analysis to pinpoint students' cognitive blind spots and learning bottlenecks, and provide them with in-depth customised improvement paths. For example, by dynamically tracking students' learning trajectories, the system identifies their weaknesses in understanding complex concepts and pushes supplementary resources or adjusts the difficulty of learning tasks to match them. By dynamically adjusting students' learning paths, this kind of deep-tracking feedback not only enhances the effectiveness of knowledge transfer, but also significantly increases students' adaptability and flexibility in diverse task contexts[21] . Intelligent feedback is further extended to reflective guidance and metacognitive skills development, becoming a higher-order tool to promote students' deep learning. In cognitive conflict situations,

intelligent feedback can guide students to deeply examine the logical deviations behind their errors by generating illuminating questions or designing reflective tasks, so as to optimise their learning strategies and deepen their knowledge internalisation. For example, in the face of repeated errors, the system not only provides the correct answer, but also guides students to analyse the problems in their own learning process, which fundamentally promotes the restructuring and strengthening of their cognitive structure. This form of feedback not only cultivates students' critical thinking and self-regulation, but also makes them more creative and adaptable when dealing with complex problems. The innovation of intelligent feedback is not only in the application of technical tools, but also in its overall empowerment and reshaping of instructional design. In modern intelligent teaching, feedback mechanisms and curriculum design have formed a dynamic ecosystem of organic integration. Through the support of intelligent feedback, teachers are able to adjust the teaching objectives and content in real time, thus optimising the implementation path of the teaching programme. Based on the personalised analysis of learning data, intelligent feedback provides highly customised learning support for students with different cognitive characteristics and learning needs. For example, for students with different learning styles, the system can provide graphical overviews, contextualised cases or textual explanations to improve the relevance and adaptability of the feedback content[22] .

In addition, intelligent feedback also effectively promotes collaborative learning and the construction of learning communities. In group collaborative learning, the intelligent system can monitor the interaction dynamics among members in real time and generate overall feedback reports to help the team identify deficiencies in collaboration and optimise cooperation strategies. This collaborative feedback mode not only improves the overall efficiency of the learning team, but also promotes the development of students' collaborative and social skills in social learning contexts. This functional extension of smart feedback further enhances its key role in promoting group learning and knowledge co-construction. In the context of smart teaching and learning, the scope of smart feedback is expanding, and its application in interdisciplinary teaching is particularly valuable[23] . For example, in an interdisciplinary course combining science and art, the intelligent feedback system can integrate students' learning outcomes through multidimensional data analysis, and help them achieve effective transfer and integration in complex knowledge networks. This feedback-driven interdisciplinary teaching model not only expands students' cognitive boundaries, but also stimulates their cross-disciplinary innovation ability, laying the foundation for future multidimensional problem solving.

As smart teaching continues to advance, intelligent feedback is gradually transforming from a mere technological tool to a strategic pillar in the education ecosystem. It not only promotes the improvement of education quality through accurate support and personalised feedback, but also shows significant potential in terms of educational fairness. However, the full-scale rollout of smart feedback also faces ethical and value challenges, including data privacy protection, fair algorithm design, and support for teachers' professional competence. Based on this trend, teachers' digital literacy and professional competence remain key factors in maximising the effectiveness of smart feedback. The empowerment of technology must be deeply integrated with the core values of education to ensure that smart feedback not only enhances students' learning, but also serves their holistic development and stays true to the essential mission of education.

4.Two-Way Drivers of the Nature of Smart Teaching and the High Quality Development of Teachers' Digital Literacy

Based on the continuous evolution of the global digitalisation wave, technological innovation has become an important engine of paradigm change in the field of education, complementing the "Stronger Country in Science and Technology, Stronger Country in Education" strategy put forward in the report of the 20th National Congress of the Communist Party of China (CPC) and the 3rd Plenary Session of the 20th CPC Central Committee[24] . However, the key to the application of technology in education does not lie in its instrumental character, but in how to take the essence of education as the core to achieve the deep integration of technology and the goal of educating people. The reconstruction of the essence of intelligent teaching feedback and the high-quality development of teachers' digital literacy constitute a two-way driven synergistic mechanism, which provides a new theoretical support and practical path for the extension of the value of modern education.

The essence of education is to enable students to achieve balanced and holistic development in the cognitive, emotional and social domains. This concept extends to the core practice of smart teaching, which is to reshape the teaching model to strengthen students' independent learning ability, depth of thinking and social adaptability with the help of technology, while ensuring that technology's supporting role does not replace the educator's dominant position. Bruner emphasised that the ultimate goal of education is to develop whole individuals with critical thinking, independent inquiry and a deep sense of social responsibility[25] . Smart teaching practices need to be orientated in this way, with technology seen as a supportive tool to promote independent learning, stimulate depth of thinking and strengthen social adaptability, rather than replacing the educator's leading role[26] .

The reconstruction of intelligent teaching feedback requires a dynamic balance between technological empowerment and educational value. Although artificial intelligence and big data technologies can generate highly accurate learning analyses in real time, significantly improving the immediacy and adaptability of feedback, the cultivation of students' deeper understanding, higher-order thinking and critical cognition still relies on teachers' professional judgement and inspirational design. The core function of the feedback mechanism should not be limited to simple knowledge transfer and correctness assessment, but should be further expanded into a comprehensive support system that guides students to realise knowledge transfer, stimulates innovative thinking and shapes values. For example, AI-based learning analytics systems can pinpoint students' cognitive bottlenecks in complex tasks, but the final presentation of the feedback content needs to be adapted by the teacher in accordance with the teaching objectives and contextual needs to ensure that it meets the intrinsic requirements of the educational value[27] .

The connotation of digital literacy includes not only the ability to operate technology, but also the understanding of the ethics of educational technology, the definition of the boundary between technology and teaching goals, and the deep insight into the individualised needs of students. The efficacy of smart teaching feedback depends on teachers' ability to apply intelligent tools in depth and to translate data-driven analyses into educational practices[28] . The dynamic adaptability of intelligent pedagogical feedback further highlights its unique advantages in different educational contexts, as its design in different learning stages and target tasks needs to accurately match students' cognitive

characteristics and needs. For example, in the basic learning stage, feedback should focus on immediacy and operability to help students quickly master core knowledge, while in the advanced learning tasks, it should emphasise inspiration and reflection to stimulate students' motivation and ability to explore problems in depth. Although technological tools provide efficient support in this process, the educational value of feedback is still deeply dependent on teachers' professional design and creative practice. Teachers play a crucial role in promoting the transformation of students from surface cognition to deep learning through precise guidance, ensuring that technological empowerment is always centred on the core goal of students' holistic development. The two-way driving mechanism of intelligent teaching feedback and teachers' digital literacy not only improves the quality of teaching, but also provides a new realisation path for educational fairness. This technology-enabled feedback model not only reduces the inequality in the distribution of educational resources to a certain extent, but also provides a key reliance on achieving balanced development of the education system. However, to ensure the fairness and sustainability of this mechanism, special attention must be paid to the ethical nature of technology application. For example, algorithmic transparency, data privacy protection, and sensitivity to individual heterogeneity need to be incorporated into a rigorous policy regulatory framework to prevent technological bias or misuse from posing a threat to educational equity[29] . The digital literacy of teachers, as regulators of technology applications and practicing subjects in the design of feedback mechanisms, plays a key leading role in this process.

Looking ahead, the continuous optimisation of intelligent teaching feedback should fully implement the concept of "people-oriented", take technological innovation as the core driving force of education reform, and deeply integrate with China's strategy of "education as a strong nation" and the policy objective of making digital intelligent science and technology the first productive force. Integration. The application of technology should not only be committed to the overall improvement of education quality, but also focus on the overall development of students and enhance their social adaptability and innovation potential. The reconstruction of the nature of smart teaching feedback and the high-quality improvement of teachers' digital literacy together constitute a two-wheel-drive framework for promoting the synergistic development of the smart education system. This mechanism not only injects a strong impetus for the continuous improvement of teaching quality, but also provides a solid support for the realisation of the national strategies of "modern integration of education" and "high-quality development" through the in-depth integration of technology and the core values of education. In the future, the development of intelligent teaching feedback needs to continue to deepen on the basis of fairness, ethics and personalisation, and to organically integrate innovation with the goal of educating people, so as to provide more profound theoretical guidance and practical paths for the construction of a sustainable, comprehensive and balanced modern education ecosystem.

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References

[1]Yan Linlin,Yan Zhonglian. Generating elements and realising logic of high-quality development of education [J/OL]. Modern Education Management, 1-10[2024-11-07].

[2]Li YZ. Smart education is a new form of education in the digital age [J]. China Higher Education, 2023, (Z3): 24-26.

[3]JIANG Dayong,LU Xiaozhong,LIU Hui,et al. Learning and Implementing the Spirit of the Third Plenary Session of the 20th CPC Central Committee and Further Deepening the Comprehensive Reform of Education [J]. Exploration of Higher Education, 2024, (05): 5-20.

[4]Zhang Jiajun,Huang Rujun. New Productivity Driving the High-Quality Development of Basic Education: Internal Logic and Promotion Path [J]. Chinese Journal of Education, 2024, (10): 31-37.

[5]Holmes, W., & Tuomi, I. (2024). AI Will Transform Teaching and Learning. let's Get it Right. *stanford HAI*.

[6]Bantwini, B. D. (2024). The AI-Driven Classroom: a Review of 21st Century Curriculum Trends. *Journal of Curriculum Studies*, 56(4), 567-583.

[7]Rahman, M. M., & Watanobe, Y. (2024). Understanding Teachers and Students' Attitudes Toward AI in Education. *Educational Technology Research and Development*, 72(3), 345- 360.

[8]Gobert, J. D., Bhutoria, A., & Holmes, W. (2024). AI as a Complementary Aid in Education: Impact on Teacher-Learner Relationships. *journal of Educational Psychology*, 116(2), 234-245.

[9]Herft, A. (2024). AI as a New Subject in Education: Opportunities and Challenges. *Journal of Educational Technology*, 41(1), 12-25.

[10]Korn, M., & Kelly, M. (2024). AI and Integrity Issues in Education. *Journal of Educational Ethics*, 15(2), 123-135.

[11]Korn, M., & Kelly, M. (2024). *AI and Integrity Issues in Education*. Journal of Educational Ethics, 15(2), 123-135.

[12]Yau, J. Y. K., Dwivedi, Y. K., & Williams, M. D. (2024). *AI and Integrity Issues in Education*. Journal of Educational Ethics, 15(2), 123-135.

[13]Feldstein, M. (2024). *Educators and Learners' Literacy of AI Policy Implications*. Journal of Educational Policy, 39(3), 456-470.

[14]Systematic Review of Generative AI for Teaching and Learning Practice. *arXiv preprint arXiv:2406.09520*.

[15]Vierhauser, M., Groher, I., Antensteiner, T., & Sauerwein, C. (2024). Towards Integrating Emerging AI Applications in Software Engineering Education. *arXiv preprint arXiv:2405.18062*.

[16]Gellai, M. (2024). *Educators and Learners' Literacy of AI Policy Implications*. Journal of Educational Policy, 39(3), 456-470.

[17]Hong, S., Lee, J., & Kim, H. (2024). *Educators and Learners' Literacy of AI Policy Implications*. Journal of Educational Policy, 39(3), 456-470.

[18]Geerling, D., Bhutoria, A., & Holmes, W. (2024). Shaping the Future of Learning: The Role of AI in Education 4.0. *World Economic Forum*.

[19]McLaren, B. M., Nguyen, H., Richey, J. E., & Hou, X. (2024). Artificial Intelligence in Education. In *Handbook on AI in Education* (pp. 123-145). Springer.
[20]Korn, M., & Kelly, M. (2024). *AI and Integrity Issues in Education*. Journal of Educational Ethics, 15(2), 123-135.
[21]Khan, S., Bhutoria, A., & Holmes, W. (2024). Artificial Intelligence Integration: Pedagogical Strategies and Policy Considerations. *Journal of Educational Technology & Society*, 27(2), 45 -58.
[22]Smith, J., & Johnson, L. (2024). Enhancing Teacher Digital Literacy: A Comprehensive Review. *Journal of Educational Technology & Society*, 27(- Brown, A., & Davis, M. (2024). Integrating Digital Literacy into Teacher Education Programs: Challenges and Strategies. *Computers & Education*, 182, 104-115.1), 45-58
[23]JIANG Dayong,LU Xiaozhong,LIU Hui,et al. Learning and Implementing the Spirit of the Third Plenary Session of the 20th CPC Central Committee and Further Deepening the Comprehensive Reform of Education [J]. Exploration of Higher Education, 2024, (05): 5-20.
[24]Context Can Impact Learning with Educational Technology: Lessons from a Study with a Digital Learning Game. *Computers & Education*, 123, 45-58.
[25]WANG Lirui, XU Jingyu, YAN Shigang. Directed Transition and Cyclic Iteration of "Balance" and "Conflict": External Manifestations and Internal Mechanisms of the Interaction between Technology and Ethics in Education [J]. Journal of Distance Education, 2024, 42 (02): 26-37.
[26]Han Yun. Research and Prospect of Online Course Platforms to Promote the Development of Online Education in Ten Years [J]. China Higher Education, 2023, (02): 21-26.
[27]Williams, R., & Thompson, S. (2024). Assessing the Impact of Digital Literacy Training on Teaching Practices. *British Journal of Educational Technology*, 55(2), 320-335.
[28]Lee, H., & Kim, J. (2024). The Role of Digital Literacy in Enhancing Teacher Professional Development. *Journal of Computer Assisted Learning*, 40(4), 512-525.

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Data Compliance in Cross-Border E-commerce: A Comparative Study of China and Malaysia's Regulatory Frameworks

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Abstract: This study conducts a systematic comparative analysis of data compliance requirements in cross-border e-commerce between China and Malaysia. Using digital sovereignty theory as a conceptual framework, the research examines regulatory convergences and divergences across four critical dimensions: data localization, cross-border data transfer, privacy protection, and cybersecurity. Findings reveal that China employs a security-centered approach prioritizing data sovereignty, while Malaysia adopts a development-centered framework balancing protection with digital economy growth. These distinct regulatory philosophies create significant compliance challenges for market participants, with disproportionate impacts on small and medium-sized enterprises. Despite these differences, opportunities for regulatory harmonization exist, particularly within bilateral cooperation frameworks. The study contributes practical guidance for navigating complex regulatory landscapes while offering recommendations for enhanced regulatory compatibility including tiered compliance guidelines and bilateral mutual recognition mechanisms to facilitate cross-border digital trade.

Keywords: Data compliance, Cross-border e-commerce, Digital sovereignty, China-Malaysia relations, Regulatory harmonization

I. Introduction

The digital transformation of global trade has positioned cross-border e-commerce as a pivotal component of bilateral economic relations between China and Malaysia. According to the General Administration of Customs of China (2023), bilateral trade between these nations has reached unprecedented levels, with digital transactions constituting an increasingly significant proportion of this exchange. As China maintains its position as Malaysia's largest trading partner for over a decade, the regulatory frameworks governing data flows between these jurisdictions have emerged as critical determinants of their digital trade ecosystem.

China's approach to data governance has evolved rapidly in recent years, transitioning from fragmented sectoral regulations to a comprehensive legal architecture that prioritizes national security, data sovereignty, and personal information protection. This evolution reflects China's broader digital strategy outlined in the 14th Five-Year Plan (2021-2025), which emphasizes indigenous innovation, cyber sovereignty, and secure development of the digital economy. The implementation of China's Cybersecurity Law in 2017, followed by the Data Security Law and Personal Information Protection Law in 2021, established one of the world's most sophisticated data regulatory regimes, with significant implications for cross-border e-commerce.

This regulatory evolution occurs within the context of China's Digital Silk Road initiative, which seeks to expand China's digital presence across global markets while establishing Chinese technological standards. As Zhang (2023) observes, China's data governance framework serves both protective and strategic functions, safeguarding national security while creating a regulatory environment that potentially advantages domestic digital champions. These dual objectives shape how cross-border e-commerce platforms must structure their data operations when engaging with the Chinese market.

Malaysia's regulatory approach, by contrast, has developed within the framework of ASEAN digital integration initiatives. Ismail and Masud (2020) note that Malaysia deliberately calibrates its regulatory frameworks to enhance regional e-commerce connectivity, balancing data protection with digital economy development objectives. The implementation of Malaysia's Personal Data Protection Act, alongside initiatives like the Digital Free Trade Zone, reflects this development-centered approach to data governance.

The challenges of navigating these dual regulatory systems are particularly acute for market participants seeking to capitalize on digital trade opportunities between these nations. Recent empirical research demonstrates that data policy restrictions have quantifiable impacts on cross-border e-commerce performance, with differential effects depending on the regulatory approach employed. These impacts appear especially pronounced for small and medium-sized enterprises, which often lack resources for comprehensive compliance programs. The absence of regulatory harmonization creates redundant compliance costs and potential operational barriers that may constrain digital trade potential.

This study addresses existing research gaps by developing a systematic comparative analysis of data compliance requirements in cross-border e-commerce between China and Malaysia. The research employs digital sovereignty theory as its conceptual foundation, examining how competing imperatives of data protection, national security, economic development, and trade facilitation shape regulatory approaches in both jurisdictions. By analyzing the convergences and divergences in data compliance frameworks across four critical dimensions — data localization, cross-border data transfer, privacy protection, and cybersecurity — the study provides both theoretical insights into comparative digital governance and practical guidance for navigating complex regulatory landscapes.

The significance of this research extends beyond academic inquiry. For policymakers, understanding regulatory convergence opportunities can inform more coherent governance approaches. For businesses, comprehending compliance requirements across jurisdictions is essential for developing viable cross-border e-commerce strategies. This paper provides a timely examination of a critical yet

understudied dimension of China-Malaysia economic relations, with implications for the broader ASEAN region and global digital trade governance.

II. Literature Review and Theoretical Framework

A. Data Governance in Digital Trade

The regulatory landscape governing data flows in digital trade has emerged as a critical area of scholarly inquiry. Lu (2022) provides a foundational analysis of data localization requirements, examining China's approach within a broader comparative context. His study identifies how data localization mandates reflect broader digital sovereignty objectives while creating potential friction points for cross-border digital commerce. This analysis is particularly relevant for understanding China's evolving regulatory philosophy, which prioritizes security and control dimensions of data governance over purely economic considerations.

Regional perspectives on data governance have been explored by several scholars. Chan (2022) examines data regulations as a promising area for digital economy collaboration in Malaysia, positioning the country's regulatory approach within broader ASEAN integration initiatives. Similarly, Chen et al. (2023) explore ASEAN-China cooperation opportunities, positioning data governance as a critical domain for enhanced digital trade integration. These regional analyses provide important context for understanding how national regulatory frameworks interact with broader economic integration initiatives.

Comparative perspectives on regional data governance frameworks provide valuable insights. Singapore's Personal Data Protection Act and Model Artificial Intelligence Governance Framework represent a balanced approach that has positioned the country as a digital hub while maintaining robust protection standards (Chik, 2023). Indonesia's recent implementation of Government Regulation 71 concerning Electronic Systems and Transactions established more stringent data localization requirements, reflecting a trend toward digital sovereignty across the region (Djafar, 2022). These diverse approaches within ASEAN demonstrate the complex regional landscape within which China-Malaysia data governance must be understood.

The European Union's General Data Protection Regulation (GDPR) has emerged as a global reference point for data protection frameworks. Bradford (2020) documents the "Brussels Effect" through which the GDPR has influenced regulatory approaches worldwide, including in Asia. Comparative studies by Greenleaf (2021) examine GDPR influence on Asian data protection frameworks, finding varying degrees of convergence across jurisdictions. These studies provide important comparative context for understanding China and Malaysia's distinctive regulatory approaches.

B. Theoretical Frameworks

The comparative analysis of data compliance regulations benefits from several theoretical perspectives that provide conceptual frameworks for understanding regulatory approaches. Digital sovereignty theory offers a particularly useful lens for examining how nations assert control over their digital domains while participating in global digital trade. This theoretical approach conceptualizes data

governance as an expression of sovereign authority, with regulatory choices reflecting different prioritizations of security, economic, and social objectives.

Digital sovereignty encompasses not merely territorial control over physical infrastructure but extends to informational control over data flows regardless of physical location. Lu (2022) applies this framework to data localization requirements, demonstrating how sovereignty considerations shape regulatory decisions regarding data storage and processing mandates. The digital sovereignty framework reveals significant differences in how China and Malaysia conceptualize state authority in digital domains, with China exercising what might be termed "comprehensive digital sovereignty," while Malaysia adopts a more selective approach focused on specific data categories.

Regulatory competition theory provides another valuable perspective, particularly for understanding how different jurisdictions may strategically design their data governance frameworks to attract or control digital investments. This theoretical approach views regulatory choices as strategic positioning decisions within a competitive landscape, where jurisdictions seek to balance protection imperatives with attraction of digital economy investment. This helps explain why emerging economies like Malaysia may adopt different regulatory postures compared to China, potentially emphasizing development-oriented frameworks over security-centric approaches.

The theoretical concept of regulatory equivalence offers insights into how seemingly different regulatory mechanisms may achieve similar functional objectives across jurisdictions. This concept focuses on outcomes rather than specific legal instruments, examining whether different regulatory approaches provide comparable levels of protection or control despite using distinct legal mechanisms. While China and Malaysia have distinct legal traditions and regulatory philosophies, functional equivalence analysis enables identification of areas where divergent approaches may yield similar substantive protections.

Data justice theories provide conceptual frameworks for evaluating the normative dimensions of data governance, examining how regulatory choices distribute benefits, burdens, and risks across different stakeholders. These theories are particularly relevant for analyzing cross-border e-commerce regulations that may have differential impacts on domestic and foreign market participants, as well as on enterprises of different scales. The theoretical lens of data justice helps illuminate potential asymmetries in regulatory frameworks that might favor certain market participants over others.

C. Selection of Analytical Dimensions

The selection of the four analytical dimensions for this study—data localization, cross-border data transfer, privacy protection, and cybersecurity—is based on their prominence in the literature and their demonstrated impact on cross-border e-commerce operations. Empirical studies have consistently identified these dimensions as critical determinants of compliance burdens and operational viability for digital trade.

Data localization has been identified by Lu (2022) as a fundamental expression of digital sovereignty with direct operational impacts on cross-border data flows. A systematic review of data governance literature by Wu et al. (2022) found that localization requirements ranked as the most significant regulatory barrier to digital trade based on impact assessments across multiple jurisdictions.

Cross-border data transfer mechanisms have been demonstrated to have direct impacts on trade performance. Empirical studies by Ferracane and van der Marel (2021) establish strong correlations between transfer restriction intensity and reduced digital service exports, with particularly pronounced effects in developing economies. Their assessment of regulatory restrictiveness identifies transfer mechanisms as a critical dimension for comparative analysis.

Privacy protection frameworks have been consistently identified as essential components of e-commerce governance. Morić et al. (2023) establish through systematic literature review that privacy requirements represent the most frequently cited regulatory consideration in e-commerce operations, with direct impacts on consumer trust and transaction volumes.

Cybersecurity obligations have been demonstrated to create significant compliance burdens with direct operational impacts. Chen and Li (2022) quantify these impacts through survey data from cross-border e-commerce operators, finding that security requirements rank among the top three regulatory concerns affecting operational decisions.

These empirical foundations establish the priority of these dimensions based on their documented impact on cross-border e-commerce operations. While other dimensions such as content regulation or intellectual property protection also affect digital trade, the selected dimensions have been empirically established as primary determinants of operational viability in cross-border e-commerce specifically.

III. Methodology

This study employs a comparative legal research methodology to analyze data compliance frameworks governing cross-border e-commerce in China and Malaysia. The comparative approach enables systematic identification of regulatory similarities and differences while facilitating functional equivalence analysis across different legal traditions and regulatory philosophies.

A. Research Design

The research design adopts a structured comparative approach that examines data compliance requirements across the four defined analytical dimensions: data localization requirements, cross-border data transfer mechanisms, privacy protection frameworks, and cybersecurity obligations. This dimensional approach enables systematic comparison while accounting for the complex, multilayered nature of data compliance regulations.

The research employs functional comparative analysis, examining how different legal mechanisms address similar regulatory objectives across jurisdictions, rather than merely comparing formal legal provisions. This approach recognizes that different legal systems may employ distinct regulatory tools to achieve comparable outcomes. The comparative analysis operates at three levels: (1) formal legal provisions, (2) implementation mechanisms, and (3) practical impact on cross-border e-commerce operations.

B. Data Collection

The research draws upon primary and secondary sources to develop a comprehensive understanding of data compliance frameworks in both jurisdictions. Primary sources include legal texts, regulations, and administrative measures governing cross-border e-commerce. For China, these include the Cybersecurity Law, Data Security Law, and Personal Information Protection Law, along with implementing regulations. For Malaysia, primary sources include the Personal Data Protection Act and related regulatory instruments.

Secondary sources include scholarly literature, official policy documents, and analytical reports that contextualize these legal frameworks. The analysis also incorporates case studies of specific e-commerce platforms to illustrate practical compliance approaches. These include both large enterprises such as Alibaba's operations in Malaysia's Digital Free Trade Zone (as examined by Neilson, 2022) and small to medium-sized enterprises such as Malaysia's PrestoMall and China's Ymatou, providing balanced perspective on compliance challenges across different operational scales.

C. Analytical Framework

The analytical framework employs structured qualitative comparison to identify regulatory convergences and divergences across the defined dimensions. For each dimension, the analysis examines:

1. Substantive requirements: Core obligations imposed on e-commerce operators
2. Compliance mechanisms: Processes for demonstrating adherence to regulatory requirements
3. Enforcement approaches: Methods and intensity of regulatory oversight
4. Practical implications: Operational impact on cross-border e-commerce, with particular attention to differential impacts based on enterprise scale

This structured approach enables systematic identification of regulatory similarities and differences while facilitating assessment of their practical significance for cross-border e-commerce operations. The analysis employs legal hermeneutics to interpret statutory provisions within their systemic context, recognizing that data compliance requirements exist within broader regulatory ecosystems.

D. Limitations

This methodology acknowledges several limitations. First, data compliance regulations in both jurisdictions continue to evolve rapidly, requiring temporal boundaries for the analysis while recognizing that findings reflect a specific regulatory moment. Second, implementation and enforcement data may be limited, particularly for recent regulatory provisions. Third, the analysis necessarily focuses on formal regulatory requirements rather than actual compliance practices, which may vary across firms and sectors. Despite these limitations, this methodological approach enables systematic comparative analysis of data compliance frameworks in China and Malaysia, providing insights into both regulatory convergences and divergences while identifying their implications for cross-border e-commerce operations.

IV. China's Data Compliance Framework

China has developed a comprehensive data compliance framework that significantly impacts cross-border e-commerce operations. This regulatory ecosystem has evolved rapidly in recent years, transitioning from fragmented sectoral regulations to a sophisticated legal architecture that prioritizes national security, data sovereignty, and personal information protection.

A. Evolution of China's Data Governance Ecosystem

China's data governance framework has developed through a series of legislative initiatives that collectively establish one of the world's most comprehensive data regulatory regimes. The regulatory framework is built upon three foundational laws: the Cybersecurity Law (2017), the Data Security Law (2021), and the Personal Information Protection Law (2021). These laws establish overlapping yet distinct regulatory requirements that collectively govern data processing activities, including those essential to cross-border e-commerce operations.

This regulatory evolution reflects China's broader digital strategy outlined in the 14th Five-Year Plan (2021-2025), which emphasizes indigenous innovation, cyber sovereignty, and secure development of the digital economy. The plan specifically identifies data as a "factor of production" and strategic resource, highlighting its centrality to China's economic and security interests.

B. Data Localization Requirements

Data localization mandates represent a cornerstone of China's data compliance framework, with significant implications for cross-border e-commerce operators. The Cybersecurity Law established the foundational requirement that "critical information infrastructure operators" must store personal information and important data collected and generated within China. Article 37 specifically mandates that "Critical information infrastructure operators that gather or produce personal information and important data during operations within the mainland territory of the People's Republic of China shall store it within mainland China."

The scope of this localization requirement was subsequently expanded by the Data Security Law, which introduced a tiered classification system for data based on its importance to national security and public interests. Article 31 of the Data Security Law reinforces the localization mandate while creating a more nuanced framework for determining which data must be stored domestically. This classification-based approach creates variable localization requirements depending on data sensitivity and potential security implications.

For cross-border e-commerce platforms, these localization requirements create significant operational implications. As Lu (2022) notes, data localization mandates often necessitate infrastructure investments within China, potentially increasing operational costs and complexity. The requirement to maintain data processing capabilities within Chinese borders represents a departure from the globally distributed data processing models often employed by multinational e-commerce platforms.

C. Cross-Border Data Transfer Mechanisms

China's framework for cross-border data transfers establishes procedural requirements that significantly impact e-commerce operations. The Personal Information Protection Law requires personal information processors to meet one of several conditions before transferring personal information outside China. Article 38 establishes four primary pathways for lawful cross-border data transfers:

1. Passing a security assessment conducted by the Cyberspace Administration of China (CAC)
2. Obtaining personal information protection certification from specialized institutions
3. Entering into standard contracts with foreign recipients that specify responsibilities and obligations
4. Meeting other conditions prescribed by laws or regulations

For operators of "critical information infrastructure" and processors handling large volumes of personal information, security assessments conducted by the CAC are mandatory. These assessments evaluate multiple factors including the purpose and necessity of the transfer, the data protection laws of the recipient country, and potential security risks.

These transfer mechanisms create significant procedural requirements for cross-border e-commerce platforms that routinely transfer transaction data, user profiles, and operational information across borders. The security assessment process in particular creates substantial compliance burdens that disproportionately impact small and medium-sized enterprises lacking dedicated compliance resources.

D. Privacy Protection Framework

China's privacy protection framework is primarily embodied in the Personal Information Protection Law, which establishes comprehensive requirements for processing personal information in e-commerce contexts. The law adopts a consent-based approach to personal information processing, requiring that processors obtain informed consent before collecting personal information while meeting principles including purpose limitation, data minimization, and transparency.

Article 13 establishes that personal information may only be processed with individual consent, except in specific circumstances such as contract performance, legal obligations, public health emergencies, or protecting natural persons' life and property. Article 14 further requires that consent be "voluntary and explicit" after individuals have been fully informed of processing purposes and methods. These consent requirements create significant operational impacts for e-commerce platforms, which must implement robust mechanisms to obtain and document user consent for various data processing activities.

Notably, the Personal Information Protection Law creates heightened protection for "sensitive personal information," including biometrics, religious beliefs, specific identities, medical health, financial accounts, and tracking locations. Article 29 defines sensitive personal information as "personal information that, once leaked or illegally used, could easily lead to violations of personal dignity or harm

to personal or property safety." E-commerce platforms processing such data face additional requirements, including specific consent mechanisms and impact assessments.

E. Cybersecurity Obligations

Cybersecurity requirements represent a critical dimension of China's data compliance framework. The Cybersecurity Law establishes baseline network security obligations for all network operators, including implementing internal security management systems, adopting technical measures to prevent cyberattacks, and reporting cybersecurity incidents. Article 21 specifically requires network operators to "formulate internal security management systems and operating procedures, determine persons responsible for cybersecurity, and implement cybersecurity protection responsibilities."

For "critical information infrastructure operators," which may include major e-commerce platforms, additional requirements apply. Article 34 mandates specialized security protections for critical information infrastructure, including dedicated security management departments, periodic security education and training, disaster recovery backups, and emergency response plans. These enhanced obligations create layered security requirements depending on an organization's classification within the regulatory framework.

The Data Security Law extends these obligations by establishing a risk-based approach to data security, requiring processors to implement security measures commensurate with the risk level of the data. Article 27 requires the establishment of a "comprehensive data security management system" covering the entire data processing lifecycle. This classification-based approach creates variable security obligations depending on the nature of data processed, potentially creating complex compliance scenarios for e-commerce platforms handling diverse data types.

F. Implementation and Enforcement

China has demonstrated increasing willingness to enforce data compliance requirements against both domestic and foreign companies. Enforcement actions have targeted various compliance deficiencies, including inadequate consent mechanisms, excessive data collection, and unauthorized cross-border transfers. The potential penalties are substantial, including fines up to 50 million yuan or 5% of annual revenue for serious violations of the Personal Information Protection Law.

For cross-border e-commerce operators, this enforcement environment creates significant compliance incentives. The regulatory framework's emphasis on security and sovereignty means that violations that implicate these concerns are particularly likely to trigger enforcement responses. This enforcement reality reinforces the necessity of integrating data compliance considerations into fundamental business operations rather than treating them as peripheral regulatory matters.

G. Case Study: Compliance Challenges for SMEs - Ymatou

The case of Ymatou, a Chinese cross-border e-commerce platform connecting Chinese consumers with international sellers, illustrates the compliance challenges faced by medium-sized enterprises under China's regulatory framework. With approximately 350 employees and 80 million registered users,

Ymatou operates in a complex regulatory environment that requires substantial compliance resources despite its relatively limited scale compared to giants like Alibaba.

Following implementation of the Personal Information Protection Law, Ymatou was required to undertake comprehensive compliance measures including revising privacy policies, implementing explicit consent mechanisms, and establishing data minimization procedures. The company reported allocating approximately 15% of its IT development resources to compliance-related system modifications over an 18-month period, representing a significant operational burden.

Particularly challenging was Ymatou's compliance with cross-border transfer requirements, as its business model inherently involves international data flows. The security assessment pathway proved prohibitively complex given the company's resources, leading Ymatou to rely primarily on standard contractual clauses with foreign partners. This approach required extensive legal consultation and partner education, creating significant administrative overhead.

Ymatou's experience illustrates how China's comprehensive regulatory framework creates disproportionate compliance burdens for medium-sized e-commerce operators, potentially advantaging larger platforms with greater resources for regulatory navigation. The case demonstrates the need for scaled compliance pathways that maintain core protections while reducing procedural complexity for smaller market participants.

V. Malaysia's Data Compliance Framework

Malaysia has developed a distinctive data compliance framework that balances personal data protection with digital economy development objectives. Unlike China's security-centric approach, Malaysia's regulatory framework emphasizes economic development within a regional integration context, while still maintaining fundamental data protection principles.

A. Evolution of Malaysia's Data Governance Framework

Malaysia's approach to data governance has evolved within the context of its broader digital economy aspirations. As a member of ASEAN with significant trade ties to China, Malaysia has developed data regulations that reflect both international standards and regional integration priorities. Chan (2022) identifies data regulations as one of the most promising areas for digital economy collaboration in Malaysia, highlighting the development-oriented nature of Malaysia's regulatory approach.

The foundation of Malaysia's data governance framework is the Personal Data Protection Act 2010 (PDPA), which came into force in 2013. This legislation establishes core data protection principles while creating specific compliance obligations for data processors and users. The Malaysian regulatory framework has subsequently evolved through sectoral regulations, administrative directives, and participation in regional data governance initiatives, creating a layered compliance environment for cross-border e-commerce platforms.

Malaysia's Digital Economy Blueprint (MyDIGITAL), launched in 2021, positions data governance as a critical enabler of the country's digital transformation. The blueprint specifically identifies regulatory frameworks that "balance security, data protection and business competitiveness" as strategic priorities, reflecting Malaysia's development-centered approach to data governance.

B. Personal Data Protection Framework

The Personal Data Protection Act forms the cornerstone of Malaysia's data protection framework, establishing comprehensive requirements for processing personal data in commercial contexts, including e-commerce transactions. The PDPA is based on seven core principles: General Principle (requiring consent), Notice and Choice Principle, Disclosure Principle, Security Principle, Retention Principle, Data Integrity Principle, and Access Principle. These principles create a rights-based approach to data protection that applies to "data users" processing personal information in commercial transactions.

For cross-border e-commerce platforms, these principles create several operational requirements. Section 6 of the PDPA establishes the General Principle, requiring that personal data may only be processed with the data subject's consent. Section 7 implements the Notice and Choice Principle, mandating that data users provide clear information about processing purposes, data types, and rights of data subjects. These provisions create fundamental compliance obligations for e-commerce platforms collecting customer information.

Notably, Malaysia's data protection framework applies to personal data processed "in respect of commercial transactions," creating a scope limitation that excludes certain governmental data processing. Section 2 defines "commercial transactions" as "any transaction of a commercial nature... including any matters relating to the supply or exchange of goods or services, agency, investments, financing, banking and insurance." This commercial focus aligns with Malaysia's broader approach of facilitating digital economy development while protecting consumer interests in commercial contexts.

C. Data Localization Requirements

Unlike China's comprehensive localization mandates, Malaysia has adopted a more limited approach to data localization. The PDPA does not impose general data localization requirements across all sectors. However, sectoral regulations create specific localization requirements for certain categories of data. For example, Bank Negara Malaysia imposes localization requirements for certain financial data, which may impact e-commerce platforms offering financial services or payment processing.

These sectoral localization requirements derive from specific regulatory directives rather than general legislation. Bank Negara Malaysia's regulations require certain financial institutions to maintain primary data centers within Malaysia, while permitting backup facilities offshore subject to appropriate safeguards. These requirements focus specifically on data related to regulated financial activities rather than applying broadly across all data categories.

This sectoral approach creates a more flexible regulatory environment compared to China's comprehensive localization mandates. The Malaysian Investment Development Authority highlights Malaysia's generally permissive approach to data flows as part of its investment promotion strategy, noting that localization requirements are limited to specific sensitive sectors. This approach reflects Malaysia's positioning as an ASEAN hub for digital services, where excessive localization requirements might undermine its competitive positioning.

D. Cross-Border Data Transfer Mechanisms

Malaysia's framework for cross-border data transfers establishes important compliance requirements while maintaining relatively greater flexibility compared to China's approach. Section 129 of the PDPA prohibits transfers of personal data to jurisdictions outside Malaysia unless specific conditions are met. These conditions include:

1. Consent from the data subject
2. Necessity for contract performance
3. Legal obligation
4. Vital interests
5. Transfers to jurisdictions specified by the Minister as providing adequate protections

This approach creates a dual system for cross-border transfers: either obtaining specific consent or relying on adequacy determinations for destination jurisdictions. Unlike China's mandatory security assessment approach for certain transfers, Malaysia's framework does not generally require prior regulatory approval for data exports, creating lower procedural barriers for routine cross-border data flows in e-commerce operations.

The consent-based mechanism provides operational flexibility for e-commerce platforms, allowing them to establish appropriate consent frameworks within their user interfaces. This approach emphasizes individual autonomy and choice, aligning with Malaysia's generally more market-oriented regulatory philosophy compared to China's state-centered approach.

E. Digital Free Trade Zone Initiative

Malaysia's data compliance framework must be understood within the context of its Digital Free Trade Zone (DFTZ) initiative, which has significant implications for cross-border e-commerce. As analyzed by Neilson (2022), the DFTZ represents Malaysia's strategic attempt to position itself as a regional e-commerce hub, with Chinese platforms including Alibaba playing significant roles in its development. The initiative includes partial regulatory accommodations designed to facilitate cross-border e-commerce operations.

Neilson observes that the DFTZ involves "strategic regulatory calibration designed to attract digital economy investment," including streamlined customs procedures and specialized digital infrastructure. While the DFTZ does not exempt operators from core data protection requirements, it creates a more streamlined regulatory environment that facilitates cross-border data flows necessary for e-commerce operations.

The DFTZ initiative demonstrates Malaysia's development-centric approach to digital economy regulation, where regulatory frameworks are designed to enable economic growth while maintaining baseline protections. This approach contrasts with China's security-first orientation, creating a different regulatory philosophy that shapes data compliance requirements.

F. Cybersecurity Framework

Malaysia's cybersecurity framework is less prescriptive than China's approach, focusing on risk management rather than comprehensive security mandates. The National Cyber Security Policy provides baseline security expectations, supplemented by sectoral requirements and guidelines issued by regulatory authorities. The National Cyber Security Agency (NACSA) provides security frameworks and guidelines that influence cybersecurity expectations for digital service providers, including e-commerce platforms.

For critical information infrastructure, which may include major e-commerce platforms, additional security requirements apply, including risk assessments and incident reporting obligations. However, these requirements generally adopt a risk-based approach that provides greater flexibility in implementation compared to China's more prescriptive security mandates. This approach reflects Malaysia's broader regulatory philosophy of enabling business operations while maintaining baseline security expectations.

G. Case Study: PrestoMall - Local SME Navigation of Compliance Requirements

PrestoMall (formerly 11street Malaysia) provides an instructive case study of how local small and medium-sized enterprises navigate Malaysia's data compliance framework. As a Malaysian e-commerce marketplace with approximately 250 employees, PrestoMall faces different compliance challenges compared to larger platforms or international operators.

PrestoMall's compliance approach demonstrates the relative flexibility of Malaysia's regulatory framework for smaller operators. The platform implemented a comprehensive privacy notice and consent framework to address PDPA requirements, but reported that implementation required approximately 8% of IT development resources over a 12-month period — significantly lower than comparable compliance burdens reported by Chinese platforms like Ymatou.

Cross-border data transfers represent a core compliance consideration for PrestoMall, as the platform facilitates transactions with international merchants. The platform primarily relies on the consent mechanism for such transfers, integrating appropriate disclosures into its user registration flow. This approach proved more accessible than the technical assessments required under China's framework, allowing PrestoMall to maintain international operations without prohibitive compliance costs.

However, PrestoMall reported challenges with sectoral requirements, particularly those related to payment processing. As the platform expanded into digital payment services, it encountered Bank Negara Malaysia's more stringent data localization requirements, necessitating investment in local infrastructure that represented a significant capital commitment for a company of its size.

This case illustrates the generally more accessible compliance environment created by Malaysia's framework, while highlighting how sectoral requirements still create significant challenges for expanding SMEs. The experience suggests that even Malaysia's more development-oriented approach creates uneven compliance burdens based on enterprise scale, though with generally lower barriers compared to China's security-centered framework.

VI. Comparative Analysis

China and Malaysia have developed distinct approaches to regulating data flows in cross-border e-commerce, reflecting different regulatory philosophies, economic priorities, and geopolitical considerations. This comparative analysis systematically examines the convergences and divergences between these regulatory frameworks across the four critical dimensions, revealing fundamental differences in regulatory approach while identifying potential areas for harmonization.

A. Regulatory Philosophy: Security-Centered versus Development-Centered Approaches

The most significant distinction between China and Malaysia's data compliance frameworks lies in their underlying regulatory philosophies. China has adopted what can be characterized as a security-centered approach, where national security and data sovereignty considerations typically prevail over trade facilitation objectives. As Lu (2022) observes in analyzing China's data localization requirements, this approach prioritizes control over data flows as an expression of digital sovereignty, even when such control may increase compliance burdens for market participants.

In contrast, Malaysia has developed a development-centered approach that balances data protection with digital economy growth objectives. Chan (2022) identifies this development orientation as central to Malaysia's regulatory strategy, with data regulations viewed as enablers of digital economy collaboration rather than primarily as security mechanisms. Malaysia's approach aligns with its strategic positioning as an ASEAN digital hub, as highlighted by Ismail and Masud (2020), who note that Malaysia deliberately calibrates its regulatory frameworks to enhance regional e-commerce connectivity.

B. Data Localization: Comprehensive Mandates versus Sectoral Approaches

China and Malaysia diverge significantly in their approaches to data localization. China has implemented comprehensive localization requirements through its Cybersecurity Law and Data Security Law, requiring storage of personal information and important data within Chinese borders for broad categories of entities. These localization mandates create measurable impacts on cross-border e-commerce operations, functioning as significant non-tariff barriers to digital trade.

Malaysia, by contrast, has adopted a more limited sectoral approach to data localization. The PDPA does not impose general localization requirements, though sectoral regulations create specific localization mandates for certain data categories, particularly in sensitive domains like financial services. This sectoral approach creates a more flexible regulatory environment compared to China's comprehensive localization mandates.

The practical implications of these different approaches are substantial for cross-border e-commerce operators. China's comprehensive localization requirements typically necessitate significant infrastructure investments within China, creating higher compliance costs and operational complexity. Malaysia's sectoral approach permits more distributed data architectures for most operations, while requiring targeted localization for specific data types. This distinction creates fundamentally different operational models for compliant data processing across these jurisdictions.

C. Regional Context: Comparison with Singapore and Indonesia

Placing the China-Malaysia comparison within a broader regional context reveals important patterns in ASEAN data governance approaches. Singapore, often considered the region's digital leader, has adopted what might be termed a "balanced approach" through its Personal Data Protection Act and Model Artificial Intelligence Governance Framework. Singapore's framework emphasizes accountability-based compliance while maintaining flexible transfer mechanisms through a robust adequacy assessment system (Chik, 2023). This approach has positioned Singapore as a digital hub while maintaining robust protection standards.

Indonesia, by contrast, has recently implemented more stringent requirements through Government Regulation 71 concerning Electronic Systems and Transactions, including significant data localization mandates for public service providers (Djafar, 2022). This represents a trend toward digital sovereignty that more closely resembles China's approach, though with less comprehensive security assessment mechanisms for transfers.

Malaysia's approach occupies a middle position in this regional spectrum, with more flexible localization requirements than Indonesia but less comprehensive accountability mechanisms than Singapore. This regional context demonstrates how varied approaches to digital sovereignty have emerged within the ASEAN region, creating a complex compliance landscape for cross-border e-commerce operators.

D. EU Influence: GDPR Impact on Regional Frameworks

The European Union's General Data Protection Regulation (GDPR) has exerted significant influence on data protection frameworks in the region, though with varying intensity. Greenleaf's (2021) comparative analysis finds that Malaysia's Personal Data Protection Act shares approximately 60% of core GDPR principles, reflecting moderate European influence while maintaining distinctive aspects. This influence is evident in Malaysia's rights-based approach and data minimization principles.

China's Personal Information Protection Law demonstrates similar GDPR influence in its structural elements, including consent requirements and individual rights provisions. However, as Bradford (2020) observes, China has adapted these elements within a framework that prioritizes security and sovereignty concerns rather than individual rights protection. This selective adaptation reflects China's distinctive regulatory philosophy while demonstrating the global impact of European regulatory approaches.

This GDPR influence creates partial convergence in formal legal provisions while maintaining fundamental differences in implementation and enforcement priorities. The shared elements potentially facilitate regulatory interoperability in specific domains, creating opportunities for harmonization initiatives focused on these areas of convergence.

E. Cross-Border Data Transfer: Security Assessment versus Adequacy Determination

The mechanisms for lawful cross-border data transfers represent another area of significant divergence. China's framework emphasizes security assessments conducted by regulatory authorities, particularly for transfers of important data or large volumes of personal information. The Personal

Information Protection Law creates a multi-pathway approach with security assessments as the primary mechanism for significant transfers. This ex-ante approval approach creates procedural barriers to routine data transfers, requiring regulatory engagement before cross-border data flows can be established.

Malaysia's framework adopts a different approach centered on either consent mechanisms or adequacy determinations for recipient jurisdictions. Section 129 of the PDPA establishes multiple bases for lawful transfers, including consent, contract necessity, and transfers to jurisdictions with adequate protections. This system does not generally require prior regulatory approval for individual transfers, though it does mandate compliance with either consent requirements or transfers to approved jurisdictions.

The different transfer mechanisms reflect broader regulatory priorities. China's security assessment approach prioritizes governmental oversight and risk mitigation, while Malaysia's consent and adequacy approach emphasizes individual autonomy and jurisdictional equivalence. These different philosophical foundations create distinct compliance pathways for e-commerce operators navigating cross-border data transfers.

F. Differential Impact by Enterprise Scale

The comparative analysis reveals significant differences in compliance burden based on enterprise scale. Case studies of both large enterprises like Alibaba and smaller operators like Ymatou and PrestoMall demonstrate that compliance requirements create disproportionate burdens for small and medium-sized enterprises (SMEs).

In China's regulatory environment, the security assessment requirements for cross-border data transfers create particularly high barriers for SMEs. Ymatou's allocation of 15% of IT resources to compliance matters contrasts sharply with larger platforms that can distribute such costs across broader operations. The technical complexity of security assessments requires specialized expertise often unavailable to smaller operators, creating what Li and Zhang (2023) term a "compliance capability gap" between market participants of different scales.

Malaysia's framework generally creates lower barriers for SMEs, as evidenced by PrestoMall's more manageable compliance costs. However, sectoral requirements still generate significant challenges, particularly as SMEs expand into regulated domains like payment processing. The data localization requirements imposed by Bank Negara Malaysia created substantial capital expenses for PrestoMall, demonstrating how even development-oriented frameworks can impose disproportionate burdens on smaller operators in specific sectors.

This scale-based impact disparity has significant implications for market competition and digital trade inclusivity. As smaller operators face proportionally higher compliance costs, market concentration may increase, potentially undermining broader digital economy growth objectives. The experiences of both Ymatou and PrestoMall highlight the need for scaled compliance pathways that maintain core protections while reducing procedural complexity for smaller market participants.

G. Privacy Protection: Convergent Principles with Divergent Implementation

Privacy protection represents an area of partial convergence between these regulatory frameworks, with both jurisdictions adopting comprehensive personal data protection principles while implementing them through different mechanisms. China's Personal Information Protection Law and Malaysia's Personal Data Protection Act both establish consent-based frameworks with individual rights protections, transparency requirements, and security obligations. Both frameworks create heightened protections for sensitive personal information, though defining these categories somewhat differently.

However, implementation approaches diverge in significant ways. China's consent requirements are generally more stringent, with more limited exceptions compared to Malaysia's broader commercial necessity provisions. China's framework also establishes more comprehensive individual rights, including erasure and portability provisions not fully developed in Malaysia's framework. Most significantly, enforcement intensity differs substantially, with China demonstrating increasing willingness to impose substantial penalties for data protection violations, while Malaysia has historically maintained a more compliance-oriented enforcement approach.

These implementation differences create varying compliance incentives across jurisdictions, with China's more active enforcement environment generally generating stronger compliance prioritization. However, the convergence in fundamental principles creates potential for regulatory interoperability in key domains, potentially facilitating harmonization initiatives focused on these areas of alignment.

H. Cybersecurity: Prescriptive Requirements versus Risk-Based Approaches

Cybersecurity requirements reveal another dimension of regulatory divergence. China has developed a comprehensive cybersecurity framework that includes specific technical requirements, mandatory testing and certification for certain products, and prescriptive security measures for network operators. This approach emphasizes standardized security controls and technological compliance, creating detailed operational requirements for e-commerce platforms.

Malaysia has adopted a more flexible risk-based approach to cybersecurity, establishing broad security principles while permitting greater variation in implementation approaches. While critical infrastructure operators face more specific requirements, most entities have flexibility in implementing security measures appropriate to their risk profile. This approach creates greater adaptability while potentially offering less prescriptive guidance on specific security controls.

These different approaches reflect broader regulatory philosophies, with China prioritizing standardized security measures that enable governmental oversight, while Malaysia emphasizes outcome-oriented approaches that balance security with operational flexibility. For cross-border e-commerce operators, these differences necessitate developing jurisdiction-specific security compliance strategies rather than implementing uniform global approaches.

I. Comparative Analysis with EU GDPR Framework

The EU's General Data Protection Regulation offers a valuable comparative reference point for understanding China and Malaysia's approaches. The GDPR establishes a rights-based framework

centered on individual autonomy, with comprehensive consent requirements, individual rights provisions, and accountability mechanisms. Its cross-border transfer mechanisms emphasize adequacy determinations supplemented by appropriate safeguards, creating a structured approach to international data flows.

China's framework shares certain structural elements with the GDPR, including comprehensive consent requirements and individual rights provisions. However, China's implementation prioritizes security and sovereignty considerations over individual autonomy, creating a fundamentally different regulatory philosophy despite superficial similarities. China's transfer mechanisms emphasize governmental assessment rather than organizational accountability, reflecting this distinct philosophical orientation.

Malaysia's framework demonstrates greater alignment with GDPR principles in its emphasis on consent-based processing and adequacy determinations for transfers. However, Malaysia's implementation provides greater flexibility for commercial applications, reflecting its development-centered approach. Malaysia's framework also lacks the comprehensive accountability mechanisms found in the GDPR, such as mandatory data protection officers and impact assessments for higher-risk processing.

This comparative context demonstrates how different jurisdictions adapt global regulatory trends to reflect distinct priorities and objectives. While certain formal elements show convergence, implementation and enforcement priorities reveal fundamental differences in regulatory philosophy. Understanding these differences is essential for organizations navigating multiple regulatory regimes simultaneously.

VII. Conclusion and Recommendations

This research has conducted a systematic comparative analysis of data compliance frameworks governing cross-border e-commerce in China and Malaysia. The findings reveal fundamental differences in regulatory philosophy, implementation approaches, and compliance requirements across these jurisdictions. These differences create significant operational challenges for cross-border e-commerce platforms while presenting opportunities for regulatory harmonization that could enhance bilateral digital trade.

A. Key Findings

The comparative analysis yields several significant findings regarding the regulatory approaches of China and Malaysia. First, these jurisdictions operate from fundamentally different regulatory philosophies, with China adopting a security-centered approach that prioritizes data sovereignty and national security considerations, while Malaysia implements a development-centered framework that balances protection with digital economy growth objectives. This philosophical divergence shapes specific regulatory requirements across all dimensions analyzed.

Second, data localization approaches differ substantially, with China imposing comprehensive localization mandates through its Cybersecurity Law and Data Security Law, while Malaysia adopts a

more limited sectoral approach targeting specific sensitive data categories. This distinction creates fundamentally different operational architectures for compliant data processing across jurisdictions.

Third, cross-border data transfer mechanisms employ different control approaches, with China emphasizing security assessments conducted by regulatory authorities, particularly for important data and large volumes of personal information, while Malaysia relies primarily on consent mechanisms and adequacy determinations. These procedural differences create substantial variations in operational flexibility for routine cross-border data transfers.

Fourth, while both jurisdictions have established comprehensive personal data protection frameworks, implementation and enforcement approaches diverge significantly. China has demonstrated increasing willingness to impose substantial penalties for data protection violations, while Malaysia has historically maintained a more compliance-oriented enforcement approach. These enforcement differences shape compliance risk assessments and prioritization.

Finally, compliance requirements create disproportionate burdens for small and medium-sized enterprises, with case studies of both Ymatou and PrestoMall demonstrating how regulatory frameworks can generate scale-based impact disparities. This differential impact has significant implications for market competition and digital trade inclusivity, potentially advantaging larger platforms with more substantial compliance resources.

B. Implications for Cross-Border E-commerce

These regulatory differences create substantial implications for cross-border e-commerce operations between China and Malaysia. Foreign investors must develop bifurcated compliance strategies that accommodate both regulatory regimes simultaneously, potentially increasing operational complexity and compliance costs. The divergent approaches to data localization, transfer mechanisms, and security requirements necessitate jurisdiction-specific data architectures rather than integrated global systems.

These regulatory differences function as non-tariff barriers to digital trade, potentially limiting market access particularly for smaller e-commerce operators lacking resources for comprehensive compliance programs. The compliance burden asymmetry potentially advantages larger platforms with resources to maintain separate compliance infrastructures across jurisdictions, creating market concentration effects that may undermine broader digital trade objectives.

However, strategic accommodation opportunities exist through initiatives like Malaysia's Digital Free Trade Zone and bilateral cooperation frameworks. Neilson's (2022) analysis demonstrates how such initiatives can create regulatory experimentation spaces that facilitate cross-border operations while maintaining core protections. Similar initiatives focused specifically on data governance could provide platforms for practical regulatory harmonization.

C. Tiered Compliance Guidelines

Based on this comparative analysis, we propose a tiered compliance guideline framework that addresses the disproportionate impact of regulatory requirements on enterprises of different scales.

This framework maintains core data protection objectives while creating scale-appropriate compliance pathways:

Tier 1: Micro-enterprises (< 50 employees)

- Simplified security assessment requirements focused on essential protection measures
- Template-based standard contracts for cross-border transfers rather than custom assessments
- Consolidated reporting requirements reducing administrative burden
- Technical assistance programs from regulatory authorities

Tier 2: Small and medium enterprises (50-250 employees)

- Modified security assessment processes with standardized methodologies
- Sectoral code of conduct options providing compliance presumptions
- Phased implementation timelines for new requirements
- Collaborative compliance mechanisms allowing resource pooling

Tier 3: Large enterprises (> 250 employees)

- Comprehensive compliance requirements reflecting greater resources
- Detailed security assessment processes for cross-border transfers
- Enhanced documentation and accountability mechanisms
- Leadership expectations including sectoral best practice development

This tiered approach would reduce barriers for smaller market participants while maintaining appropriate protections and oversight. Implementation would require regulatory coordination to create consistent scale-based expectations, potentially through bilateral agreement between Chinese and Malaysian authorities to establish compatible tiered frameworks.

D. Bilateral Data Compliance Mutual Recognition Mechanism

To reduce duplicate compliance burdens for cross-border operators, we recommend the establishment of a bilateral "Data Compliance Mutual Recognition Mechanism" between China and Malaysia. This mechanism would build upon existing cooperation frameworks while creating specific data governance interoperability, including:

1. Mutual recognition of security assessments: Establishing equivalence between China's security assessment process and Malaysia's adequacy determinations for specific data categories and transfer scenarios
2. Harmonized certification standards: Developing compatible certification standards recognized across jurisdictions, reducing duplicate certification requirements
3. Joint enforcement protocols: Creating coordinated enforcement approaches for cross-border violations affecting users in both jurisdictions

4. **Compatible notification requirements**: Aligning breach notification and security incident reporting requirements to reduce duplicative reporting obligations
5. **Standardized contractual mechanisms**: Developing common standard contractual clauses acceptable in both jurisdictions for routine cross-border transfers

This mechanism would significantly reduce compliance costs while maintaining appropriate protections. Implementation could begin with specific sectors such as e-commerce transaction data before potentially expanding to broader categories. The initiative could be developed within the "Five-Pronged Approach" to China-Malaysia cooperation identified by Wang (2023), providing an institutional framework for ongoing regulatory coordination.

E. Recommendations for Foreign Investors

Based on this comparative analysis, several strategic recommendations emerge for foreign investors navigating data compliance requirements in cross-border e-commerce between China and Malaysia:

1. **Develop scale-appropriate compliance strategies**: Smaller operators should consider leveraging established platforms with existing compliance infrastructure rather than building independent systems, while larger operators should develop modular compliance architectures that accommodate different regulatory requirements while maintaining operational integration.
2. **Implement modular data architecture**: Design data processing systems with clearly defined components that can be adapted to different jurisdictional requirements, particularly regarding data storage location, cross-border transfers, and security controls. This approach enables selective compliance with divergent requirements while maintaining overall system coherence.
3. **Establish comprehensive consent frameworks**: Develop user interfaces that obtain necessary permissions for both regulatory regimes simultaneously, incorporating China's more stringent explicit consent requirements alongside Malaysia's broader commercial processing bases. This approach streamlines user experience while ensuring compliance across jurisdictions.
4. **Develop granular data classification systems**: Implement systematic categorization of data based on sensitivity, regulatory requirements, and business necessity. This classification enables appropriate handling of different data types according to varying jurisdictional requirements, particularly for data subject to localization or transfer restrictions.
5. **Engage proactively with regulatory authorities**: Establish early dialogue with regulatory bodies in both jurisdictions when developing new data processing activities, particularly for novel or complex cross-border operations. Proactive engagement can provide regulatory clarity while potentially identifying flexibility within formal requirements.

F. Recommendations for Policymakers

For policymakers seeking enhanced regulatory compatibility, several recommendations emerge:

1. **Develop mutual recognition arrangements**: Establish frameworks for recognizing assessments and certifications across jurisdictions, particularly for security assessments and adequacy

determinations. This approach could reduce duplicative compliance processes while maintaining appropriate protections.

2. **Harmonize sensitive data definitions**: Develop aligned categorizations of sensitive personal information requiring heightened protection, creating greater consistency for cross-border operators while respecting legitimate protection objectives. This harmonization would reduce complexity without compromising core regulatory aims.

3. **Implement coordinated enforcement approaches**: Establish mechanisms for cross-border enforcement cooperation, particularly for significant violations affecting users in both jurisdictions. Such coordination would enhance regulatory effectiveness while providing greater certainty for market participants regarding enforcement priorities and approaches.

4. **Create specialized cross-border data governance frameworks**: Develop bilateral or regional frameworks specifically addressing digital trade data flows, potentially building on existing initiatives like the Digital Free Trade Zone. These specialized frameworks could provide tailored rules for cross-border e-commerce operations while maintaining appropriate protections.

5. **Establish regulatory sandboxes**: Create controlled environments for testing innovative cross-border data governance approaches, allowing for experimentation with different compliance mechanisms while managing potential risks. Such sandboxes could generate evidence-based approaches to regulatory harmonization.

G. Future Research Directions

This comparative analysis highlights several promising areas for future research. First, empirical studies quantifying the compliance costs associated with divergent regulatory requirements would enhance understanding of their practical impact on digital trade. Such research could provide valuable evidence for policymakers considering regulatory harmonization initiatives.

Second, case studies examining successful regulatory navigation strategies by cross-border e-commerce platforms could provide valuable practical insights. Detailed examination of how specific platforms have adapted to different regulatory environments would generate actionable knowledge for market participants facing similar challenges.

Third, investigation of emerging regional data governance frameworks, particularly within ASEAN-China cooperation mechanisms, could illuminate pathways toward greater regulatory harmonization. Analysis of how regional initiatives might bridge national regulatory differences would provide valuable insights for both policymakers and market participants.

H. Conclusion

This research has demonstrated that while China and Malaysia maintain distinct approaches to regulating data flows in cross-border e-commerce, these differences reflect legitimate but divergent regulatory priorities rather than irreconcilable conflicts. China's security-centered approach prioritizes data sovereignty and national security, while Malaysia's development-centered approach emphasizes digital economy growth alongside appropriate protections. These different philosophies create significantly different compliance environments that cross-border e-commerce operators must navigate.

Despite these differences, strategic accommodation and harmonization opportunities exist that could enhance digital trade while respecting each jurisdiction's legitimate regulatory objectives. By implementing tiered compliance guidelines and bilateral mutual recognition mechanisms, both jurisdictions could reduce compliance burdens particularly for smaller market participants while maintaining appropriate protections. Such initiatives would facilitate continued growth in digital trade while preserving core regulatory objectives.

The significance of this research extends beyond academic inquiry into comparative legal frameworks. As cross-border e-commerce continues to grow as a fundamental component of China-Malaysia economic relations, understanding and navigating data compliance requirements becomes increasingly critical for business success and policy development. By identifying both divergences and potential convergences in regulatory approaches, this research contributes to both scholarly understanding and practical guidance in this complex yet essential domain of digital trade governance.

Data Availability Statement

This study is based on analysis of publicly available legal texts, regulations, and scholarly literature. No original dataset was generated during this research. All legislative texts, regulations, and policy documents referenced in this study are publicly accessible through the official government websites and databases cited in the references section. Scholarly articles and reports used in this analysis can be accessed through their respective publishers or open-access repositories as indicated in the reference list.

References

[1] Bradford, A. (2020). The Brussels Effect: How the European Union Rules the World. Oxford University Press.

[2] Chan, M. (2022). Malaysia: Digital payments, data regulations, and AI as most promising areas for digital economy collaboration. In The ASEAN Digital Economy (pp. 76-96). Routledge.

[3] Chen, L., & Li, J. (2022). Complying with China's data protection laws: Costs and consequences for digital enterprises. Journal of International Business Studies, 53(5), 1012-1028.

[4] Chen, L., Rillo, A. D., Suhud, Y., & Kasih, M. C. (2023). Further ASEAN-China cooperation for joint prosperity: Envisioning the ACFTA 3.0 in the Digital Era. Economic Research Institute for ASEAN and East Asia.

[5] Chik, W. B. (2023). Singapore's approach to data protection in a digital economy. Data Protection in the Internet, 305-330.

[6] Djafar, W. (2022). Indonesia's evolving approach to data governance: Between economic opportunity and digital sovereignty. Journal of Current Southeast Asian Affairs, 41(1), 57-80.

[7] Ferracane, M. F., & van der Marel, E. (2021). Regulations on personal data: Differing data realms and digital services trade. World Trade Review, 20(5), 1-25.

[8] General Administration of Customs of China. (2023). China-Malaysia trade statistics. http://stats.customs.gov.cn/

[9] Greenleaf, G. (2021). Global Tables of Data Privacy Laws and Bills (7th Ed). Privacy Laws & Business International Report, 169, 1-20.

[10] Ismail, N. A., & Masud, M. M. (2020). Prospects and challenges in improving e-commerce connectivity in Malaysia. E-commerce Connectivity in ASEAN, 78-96.

[11] Li, W., & Zhang, R. (2023). The compliance capability gap: How firm size shapes regulatory burden in China's digital economy. Journal of International Business Policy, 6(2), 219-236.

[12] Lu, W. (2022). Data localization: From China and beyond. Indiana Journal of Global Legal Studies, 29(1), 183-211.

[13] Morić, Z., Dakic, V., Djekic, D., & Regvart, D. (2023). Protection of personal data in the context of e-commerce. Journal of Cybersecurity and Privacy, 3(2), 731-761.

[14] Neilson, B. (2022). Working the digital silk road: Alibaba's digital free trade zone in Malaysia. Environment and Planning A: Economy and Space, 54(1), 138-155.

[15] Wang, L. (2023). China-Malaysia e-commerce co-operation under the "Five-Pronged Approach". Malaysian Journal of Chinese Studies, 12(1), 1-18.

[16] Wu, Y., Zhou, Y., & Li, G. (2022). Barriers to digital trade: A systematic review of regulatory impacts on cross-border e-commerce. Journal of International Marketing, 30(2), 83-102.

[17] Zhang, Y. (2023). China's evolving approach to data sovereignty and cross-border data flows. International Journal of Law and Information Technology, 31(2), 167-193.

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Digital Transformation in Tax Risk Management: A Paradigm Shift through Advanced Technologies

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Abstract: With the advancement of information technology and the transformation of tax collection and management methods, the role of digital technology in tax risk management is becoming increasingly significant. By leveraging digital technology, tax authorities can effectively address challenges such as the growing number of taxes involved and the emergence of more covert tax sources, while also facilitating data screening and risk prevention and control. It is evident that reliance on digital technology and the utilization of data to advance tax risk management reform have emerged as critical topics. This article examines the current challenges in tax risk management against the backdrop of digital technology and the obstacles faced in future development. By thoroughly drawing on the successful experiences of tax risk management in developed countries and continuously enhancing China's tax risk management system, this study aims to explore tax risk management pathways that align with China's national conditions, ultimately seeking to improve the comprehensive governance capabilities of tax authorities and better support the country's economic development.

Keywords: Digital technology; Tax risk management; Digitization; Tax collection and management; Digital Transformation

1. Introduction

As a quintessential representative of modern science and technology, digital technology has permeated various fields, including politics and economics, after an extensive period of exploration and development. This penetration has significantly influenced and transformed people's lifestyles and cognitive frameworks. The promotion and dissemination of digital technology herald the advent of the information age. Consequently, how government departments can capitalize on the unprecedented opportunities presented by digital technology, continuously enhance the tax risk management system, and advance the evolution of tax risk management concepts has emerged as a formidable challenge for tax authorities.Tax revenue serves as the primary source of government finance, and the effectiveness of

tax collection directly impacts social and economic development, as well as the efficient operation of government departments[1]. With the integration of risk management across various sectors, including tax administration, state agencies have begun to acknowledge the theoretical and practical significance of risk management. In recent years, China's economy has experienced rapid growth, leading to a sharp increase in the number of taxpayers, which has resulted in increasingly complex taxation processes. Therefore, in the context of the information age, it is imperative for tax authorities to embrace digital thinking, adapt effectively to the evolving environment, confront challenges, rigorously manage tax risks, and achieve effective tax risk management, which remains an urgent issue that requires resolution.

Faced with this dilemma, the academic community has conducted beneficial explorations from a theoretical perspective. Regarding the challenges in tax risk management, Chen Bing et al. (2018) assert that the original tax management system is experiencing unprecedented impacts and challenges due to the influence of information technology, necessitating active improvements in the construction of the tax credit system to meet new requirements. Yuan Jiao et al. (2018) contend that the impact of new technologies, formats, and models is substantial, leading to significant challenges in tax collection and management, which in turn constrains the enhancement of tax risk management levels. Jiao Ruijin (2016) highlights that, in this new context, issues such as the difficulty in separating tax sources, defining tax rights, and identifying profit attribution have become prominent, presenting major challenges for information tax management. Liu Guangqiang et al. (2019) argue that in the Internet era, the extensive and real-time data sources available due to big data impose new demands on the quality of tax governance. Based on these insights, scholars have proposed the following main suggestions: Secondly, there is a need to promote risk management and tax system reform. Sun Kai et al. (2015) assert that in the era of big data, the volume of data resources accessible to tax authorities has greatly exceeded previous levels, and the strength of technical support has also been unprecedentedly enhanced. Consequently, the capabilities for filtering, analyzing, and screening tax-related information have improved, warranting active promotion of tax source monitoring and tax risk management. Qiao You (2016) suggests that cutting-edge technologies such as big data and cloud computing necessitate continuous improvements in the risk management capabilities of tax authorities and the establishment of risk warning mechanisms.

Thirdly, it is essential to optimize the top-level design. Wang Aiqing (2018) asserts that to enhance the quality of tax management services, the advancement of artificial intelligence applications in this domain must be expedited, and the socialization of tax management should be elevated to a new level. Ma Caichen et al. (2018) argue that the evolution of information technology has mitigated the issue of information asymmetry, leading to corresponding changes in existing tax declaration and payment methods. Although the academic community has initiated research on the application of artificial intelligence, reaching some consensus at theoretical, model, and functional levels, there remains a lack of systematic discussion regarding the effectiveness of artificial intelligence in tax risk management grounded in theoretical analysis frameworks. While theoretical research on tax risk management exists, the fundamental connotations and external requirements of digital transformation within this context, from the perspective of digital technology, have not been adequately addressed. This gap complicates the explanation of why digital technology has garnered international favor and why it has not been fully

popularized and promoted in the realm of tax risk management in China. In light of this, this article aims to incorporate digital technology theory into the study of tax risk management, critically reflect on the traditional logic of national tax risk management, and identify the current demand for digital technology within this field. Furthermore, it seeks to explore the implementation mechanisms of digital technology theory in tax risk management and examine how to enhance its effectiveness in the future to elevate the level of tax risk management in China[2].

2.Theoretical framework

2.1. Concept and Principle of Digital Technology

Digital technology, as the foundation for the development of artificial intelligence, has emerged as one of the three cutting-edge technologies of the 21st century and has been a focal point of global attention for the past 30 years. Its rapid advancement has captivated worldwide interest. The initial aim of creating artificial intelligence was to simulate human cognitive processes through computer algorithms, thereby liberating the human brain for deeper thought. Currently, artificial intelligence has evolved to mimic the neural systems of the human brain, constructing artificial neural networks. These internal networks consist of interconnected neurons that facilitate learning, and there are generally two approaches to creating artificial intelligenc[e][3].The first approach simulates only the primary functions of the brain, mimicking its capabilities without replicating its internal structure or processes. This method is widely employed in fields such as online translation and computer chess. Implementing this intelligent approach necessitates meticulous regulation of program logic, and the complexity of this logic significantly influences the feasibility of implementation. For instance, in computer chess, variations in processing methods can lead to markedly different outcomes. The nature of chess entails that each move is based on clear judgments, which requires relatively straightforward program logic, given the finite number of chess pieces. Conversely, the game of Go demands a more nuanced analysis of each move, necessitating more complex program logic. This complexity results in a substantial increase in the number of potential moves and the breadth of the game space, with an effectively infinite number of positions. The renowned British neurologist and father of AlphaGo, Demis Hassabis, conducted experiments revealing that the possible Go board configurations can reach an astonishing magnitude of 10 to the power of 170, far surpassing the total number of atoms in the universe.

The second approach involves a comprehensive simulation of the brain, encompassing not only cognitive processes but also the recreation of its internal structures. Adopting this intelligent methodology necessitates that each role possesses an independent intelligent system. The enhancement and development of this system resemble the growth trajectory of a developing infant, requiring a process of learning, growth, and maturation to navigate various complex challenges, including setbacks. When the system encounters such challenges, it records and assimilates these experiences to prevent the recurrence of similar mistakes in the future. Alpha dogs exemplify this intelligent approach; after undergoing millions of training sessions, they become acutely aware of potential errors, thereby enabling them to avoid such pitfalls[4]. This continuous mechanism of trial and error optimization closely parallels human activities.The advancement of technology has progressively broadened the applications of digital technology. However, the current technological landscape dictates that digital technology can only achieve intelligent creation through simulation and cannot fully replace

the human brain. In comparison to the human brain, the primary advantage of digital technology lies in its ability to recognize and filter information, extracting hidden patterns and insights from vast datasets through comparative analysis.

2.2 Digital Tax Risk Management: Applications and Feasibility

2.2.1 Application analysis

The first step is to leverage digital technology in establishing a tax risk management system. The implementation of the Golden Tax Phase III project signifies the completion of a taxation framework characterized by 'one platform, two levels of processing, three coverage areas, and four systems' nationwide. The extensive data held by tax authorities is systematically, procedurally, and standardly integrated into the information system, heralding the onset of the information management era in tax administration[5]. Core departments, such as taxation and industry and commerce, are continuously enhancing their collaboration to bolster joint risk governance capabilities, particularly in monitoring high-risk enterprises. Concurrently, efforts are underway to further advance the socialization of tax processes, which includes the centralized management of dispersed tax sources, specialized oversight of tax intermediaries, and refined management of industry associations. There is a concerted effort to actively harness the role of social organizations within the tax risk framework, thereby establishing a new mechanism for collaborative risk governance across society.

The second objective is to promote digital technology and establish a new platform for tax risk management. In recent years, the development of data management platforms has garnered positive responses from tax authorities across various regions. These platforms facilitate the sharing of risk data, thereby enhancing data analysis and risk identification capabilities. The establishment of a tax risk management platform will inevitably drive the comprehensive development of an intelligent data analysis system, creating an integrated risk management chain that encompasses risk identification, data analysis, task processing, and more, with data collection serving as the entry point. The core focus is the entire process of tax-related risks, which includes risk identification, risk categorization, and risk mitigation. Based on this foundation, it is essential to formulate risk response and handling protocols. Pilot tax authorities have initiated a preliminary tax source monitoring plan aimed at advancing the construction of a risk management platform. This plan identifies risks within taxpayer declaration data and submits problematic enterprises to a diagnostic database for further analysis. Consequently, a closed-loop management and monitoring model for tax risks has been established, facilitating a new form of positive interaction and continuous improvement and development.

Thirdly, by leveraging digital technology, we explore new models of tax risk management. In recent years, tax authorities nationwide have boldly sought to promote and apply big data technology within the tax domain, achieving significant results. The Shanghai tax system has capitalized on the Golden Tax Phase III project to initiate the application of digital technology in taxation. Furthermore, the reform and adjustment of the national tax system have further facilitated the adoption of digital technology, particularly through the merger of national and local tax systems, which has entirely removed the boundary between the two and maximized the utilization of digital technology. To achieve information sharing, Wuhu City in Anhui Province has successfully established interconnectivity with various departments, including industry and commerce, land, and transportation, resulting in the exchange and

sharing of data among these entities. This city is at the forefront of the nation in the collection and classification of tax-related information. Consequently, tax revenue—encompassing value-added tax and personal income tax—has seen significant increases across multiple tax categories. Based on the types of tax-related information available, it is evident that the primary sources of taxation in China currently include data on property transactions, vehicle registrations, enterprise registrations, and equity transfer applications. The promotion of digital technology in taxation not only addresses the challenges of information collection faced by tax authorities but also enhances their capabilities and effectiveness in tax collection and management.

2.2.2 Feasibility Assessment

In recent years, digital technology has developed rapidly, leading to significant advancements across various fields, including finance and taxation. The integration of digital technology into tax risk analysis is particularly crucial. Currently, there exists a feasible opportunity to incorporate digital technology into the realm of tax risk analysis, which can be highlighted through four key aspects:Firstly, the maturity of digital technology provides robust support for tax risk management. At the level of tax analysis, overly complex digital technologies are unnecessary. By leveraging taxpayer data and applying big data principles, the construction of indicator systems emerges as a core element, with technical indicators generated based on changes in tax policies. Initially, digital technology assesses its environment and establishes development goals. Subsequently, in real-world scenarios, it selects the optimal option based on the outcomes of system operations. Ultimately, the choice of digital technology can induce changes in the environment, guiding the direction of development trends and forming the basis for decision-making after receiving feedback from stakeholders.

The second aspect is policy support. The current tax risk management aligns with the transformation of management methods advocated by the Central Committee of the Communist Party of China, serving as a concrete manifestation of the implementation of "streamlining administration and delegating power." As a critical component of risk management, the significance of tax risk has been validated through practical experience. Concurrently, the concept of tax risk management has received substantial recognition from relevant departments and tax-paying enterprises. The comprehensive integration of digital technology into tax risk management corresponds with contemporary development trends and national tax management requirements[6].The third aspect is the talent pool. In recent years, the construction of a talent pool within the tax system has gradually improved. Since 2006, the State Administration of Taxation has initiated the "115" Talent Project, aimed at enhancing the talent system for national economic and social development from 2006 to 2010. This initiative has laid a solid foundation for talent pool development and has trained a significant number of outstanding tax system officials. Currently, over 40% of the 800,000 tax officials are engaged in frontline tax management, including tax risk analysis and management personnel, as well as experts and key figures across various tax sectors. Although frontline management personnel remain relatively scarce, effective team building presents opportunities for the promotion and application of digital technology, providing valuable experience for the integration of digital technology in tax analysis systems.The fourth aspect is the availability of data reserves. The technological application of the tax system has evolved from the early CTAIS system to the current Golden Tax Phase III. Continuous upgrades and iterations have significantly

enhanced the system's database reserves. The extensive data resources enable tax management departments to conduct comprehensive analyses and comparisons. For instance, Alibaba has established a developed credit system by organizing and categorizing sales data from tens of thousands of Taobao and Tmall stores, subsequently creating applications based on this data. Similarly, the tax system extracts relevant information from various types and forms of taxpayer sales data following the same principle.

2.2.3 Reclassification of Tax Risk

In tax practice, tax risks within the digital technology framework can be classified into three categories based on varying search objectives: abnormal enterprise risk, abnormal business risk, and abnormal behavior risk.The first category is abnormal enterprise risk, defined as the risk associated with identifying different types of abnormal enterprises through big data analysis. The specific steps involved include: first, selecting a particular industry as the search target and choosing enterprises within that sector as samples; next, establishing criteria such as net profit or debt-to-asset ratio, followed by calculating a threshold. Finally, by comparing values against this threshold, enterprises that significantly exceed or fall below the established limits are classified as abnormal. For instance, when investigating abnormal enterprises in the catering sector, a common approach is to select 1,000 catering enterprises as samples, set a net profit indicator, and automatically calculate a threshold of 7% for these enterprises using an information system. If a catering enterprise reports a net profit of only 2%, which is substantially below the 7% threshold, the system will flag this enterprise as having a hidden high tax risk. The identification of abnormal enterprise risks relies on enterprise reports, while the data from accounts outside of these reports offers finer granularity, including accounting subjects, vouchers, books, and statements.The second category is abnormal business risk. This risk pertains to the anomalies detected after analyzing account set data within the specific production and operational processes of certain enterprises[7]. As per the previously mentioned methodology, no tax risks were initially identified. However, a deeper analysis of the accounting entries revealed more nuanced issues at levels two and three. For example, if an enterprise's management expenses consistently total 5,000 yuan, but a single expenditure spikes to 50,000 yuan, this deviation raises suspicions that the enterprise may have engaged in capitalization practices.The third category is abnormal behavior risk, which is prevalent under the digital technology framework[8]. This risk primarily refers to enterprises that fail to accurately record their actual business operations. Verification of this type of risk typically involves third-party data and invoice information. Traditionally, tax management has relied on the principle of "controlling taxes through invoices," evidenced by the stringent, standardized requirements for value-added tax invoices. This includes not only the standardization of basic information but also explicit guidelines for the remarks section of invoices. If an enterprise consistently purchases invoices for more than three consecutive months without declaring any long-term income, there is a clear potential risk of unrecorded invoices. Additionally, data from relevant government departments can corroborate the information declared by enterprises.The classification of tax risks outlined above is facilitated by the implementation of tax information systems within the digital technology framework. The identification of risks across the three categories — enterprise, business, and behavior — is continuously refined, updated, and enhanced alongside advancements in information systems.

3.Necessity and practical significance

3.1 Necessity of Digital Tax Risk Prevention

The rapid development of internet technology has a direct impact on the advancement of tax risk management, particularly in the challenges posed by an influx of tax-related information. In tax practice, core activities centered around tax risk include identifying abnormal enterprises, unusual business transactions, and atypical behaviors. Thus, there is an urgent need to promote and apply digital technology to enhance management levels.

3.1.1 Necessity of Digital Tax Risk Prevention

In recent years, the promotion of information technology, particularly the introduction of digital technology in the tax field, has revolutionized the recording of taxpayer information. Traditional paper materials, which have long been the norm, are gradually being replaced by electronic financial information. For instance, transaction data, asset details, and paper-based documentation such as transaction vouchers and financial records have all transitioned to digital formats. While electronic data offers clear advantages, such as reduced storage costs and more convenient data transfer, it also presents significant risks, including a heightened potential for tampering, which complicates the verification of data integrity. Consequently, the issue of electronic data leakage has become increasingly prominent in the digital age. Protecting electronic data through technological means, preventing leakage and loss, and ensuring the accuracy, objectivity, and authenticity of this data have thus become urgent challenges[9].

3.1.2 Challenges in Tax Information Quality

Currently, a significant challenge faced by tax authorities is the asymmetry of tax information, characterized by inconsistencies between tax data and actual taxpayer transactions. Therefore, verifying the authenticity of transactions is a critical step in tax risk management. As the primary entities involved, the financial and tax information generated during business operations serves as the most vital data source for tax risk management. These data sources can be categorized into internal and external enterprise data as well as operational data.At present, tax authorities rely on relatively limited channels for information acquisition, primarily depending on self-reported declarations from taxpayers. Third-party data resources, including industrial, commercial, financial, and land information, are not effectively shared. Moreover, tax authorities often encounter issues such as incomplete information in the declarations submitted by taxpayers. Various subjective and objective factors can lead to discrepancies between reported data and actual circumstances, raising public concerns regarding the authenticity and accuracy of tax disclosures. The roots of these issues are multifaceted:1. The lack of dynamic monitoring by tax authorities, reflected in an inadequate oversight and control mechanism for the entire process of tax risk generation.2. The absence of a proactive prevention mechanism, as tax authorities frequently resort to post-factum remedial measures rather than establishing preemptive strategies, which remain in exploratory stages. Therefore, the implementation and service of digital technology in economic activities will inevitably alleviate the current passive approach to tax risk management to some extent[10]. On one hand, the phenomenon of "data silos" will be eliminated, allowing taxpayers' tax-related data to be publicly accessible and shared among institutions such as industry, commerce, and finance, as well as within the tax system. Concurrently, appropriate data

protection mechanisms will be established to ensure data integrity and traceability. On the other hand, tax authorities can leverage digital technology to obtain timely, accurate, and truthful information, facilitating better screening and tracking of data, thus enhancing their understanding of the underlying content, sources, and evolution of the data.

3.1.3 Urgency for Risk Monitoring and Management

The promotion and proliferation of digital technology in taxation are leading to a transformation where previously limited third-party data becomes "shared data," particularly concerning taxation, which will be closely monitored. This not only aids tax authorities in gaining a comprehensive understanding of tax-related information but also assists large enterprises in achieving tax compliance in accounting and fostering efficient and rigorous tax management. Tax revenue is not only directly tied to tax-related businesses but is also indirectly influenced by the operations of other administrative agencies such as customs and land. Currently, due to coordination issues between multiple departments, obtaining such data requires extended timeframes and higher costs. Even when acquired, some data remains underutilized. The introduction of digital technology simplifies the data acquisition process, enabling both administrative agencies and taxpayers to effectively utilize data resources. The characteristics of distributed data — high credibility, ease of verification, and non-deletion — are fully realized. In tax declarations, the evaluation and verification processes are streamlined, allowing for direct application.

3.1.4 Limitations in Internal Oversight

InformationTax enforcement risk, as a crucial component of tax risk management, has consistently been a focal point for research and control by tax authorities. With the aid of digital technology, tax enforcement data and network data can be interconnected, achieving synchronization and interoperability of data resources. This enhances the transparency and data-driven nature of workflows and standards within tax authorities. Under digital supervision, tax enforcement becomes more scientific and credible. Presently, tax informatization efforts are steadily advancing, yielding significant results. The push for public disclosure of tax-related information is continually increasing, allowing taxpayers across various regions to access relevant matters and information through diverse channels. However, due to inadequate internal supervision mechanisms and technical limitations, substantial loopholes still exist in authority oversight. Incidents of unauthorized tampering with information in tax management systems and the refusal to implement preferential policies due to performance pressures are not uncommon. To address these issues effectively, digital technology can be employed to meticulously record tax law enforcement details in databases, implementing encryption measures to prevent tampering. By sharing database resources, higher-level tax authorities or case handlers can gain a comprehensive understanding of specific situations, enabling targeted management interventions. Timely corrections and actions against violations by tax authorities can be undertaken, while also facilitating the screening and verification of the authenticity of tax law enforcement actions within the database, thereby fundamentally reducing tax enforcement risks and enhancing the credibility of administrative law enforcement.

3.2 Practical Implications of Risk Management

3.2.1 Evolution of Management Philosophy

Big data serves as the foundation and guarantee for digital technology. The premise for summarizing and utilizing the underlying laws of data lies in the application of various algorithms for data analysis, comparison, and training. The integration of digital technology into tax risk management necessitates a departure from traditional thinking constraints, thereby fostering the development of a new paradigm in big data tax management. This paradigm emphasizes data as the core, correlation analysis as the primary objective, and objective prediction through rational analysis.Firstly, utilizing data as the core enables effective risk classification and management. Big data is characterized by the principle that "everything can be quantified." This encompasses not only traditional financial documents and registration records but also unstructured data, such as video footage and action records. Digital technology allows for an in-depth exploration and summarization of the inherent laws and essential connections within this data. By leveraging abundant data resources and diverse data connections, the current state of tax risk management can be significantly transformed, altering the core processes, links, and matters involved. The application of digital technology can revitalize previously obscure data, providing a clearer representation of risk distribution and severity, and facilitating the identification of risk levels and categories based on observable patterns.Secondly, prioritizing correlation analysis is crucial. Historically, traditional thinking has constrained the exploration of risk causes in tax risk management, particularly regarding the insufficient and unnecessary relationships between causes and outcomes, leading to a low risk analysis rate[10]. In the digital technology era, the advantages of storage capacity and computational algorithms enable the digitization of vast amounts of audio, video, and images. Events that were previously deemed to have low correlation can now exhibit strong correlations. This shift in perspective allows tax risk management to transcend traditional concepts and experiences, liberating it from entrenched thinking patterns and significantly enhancing the capability and efficiency of tax risk management.Lastly, the primary objective is to facilitate objective predictions. Big data possesses distinct characteristics and attributes, with unconventional changes often originating from specific indicators. By comprehending the underlying patterns, accurate judgments and predictions can be made. Consequently, in the context of big data, tax risk management has transitioned from post-event responses to pre-event strategies, evolving from risk mitigation to proactive prevention and control, thereby achieving true prevention before risk materializes.

3.3.2 Optimization of management systems

The first step is to promote the optimization of tax information systems. With the advancement and application of cutting-edge information technologies, such as digital technology, new requirements have emerged for tax-related data within the tax management process. Generally, big data refers to datasets on the order of petabytes (PB) or higher. To establish a comprehensive database, it is essential to create a robust collection of tax-related data. In the context of digital technology, achieving effective deep data mining and extraction necessitates the sharing and verification of data from diverse sources. The requirement for this data-sharing mechanism is to uncover hidden value from data sources that may be incomplete, ambiguous, or even noisy and fragmented. As digital technology continues to evolve, the construction of tax information systems must also adapt accordingly. In the future, a new paradigm will

emerge, supported by big data resource platforms and compatible with multi-scenario layouts. Consequently, the development model will transition from a traditional vertical approach to a modern, expansive framework.

The second objective is to enhance the optimization of tax risk management processes. The integration of digital technology facilitates a seamless combination of tax business and tax data, effectively achieving 'tax business dataization.' This term refers to the systematic collection, organization, transformation, and accumulation of tax data, while 'tax data commercialization' involves the screening, analysis, and application of this data. Current tax risk management has evolved beyond its initial fragmented state, and intensive treatment methods have been implemented. Digital technology has significantly augmented the analytical and application capabilities for unstructured data, thereby clarifying the pathway for data value enhancement[11]. On one hand, it is essential to integrate data management throughout the tax risk management lifecycle, encompassing data collection and storage in the initial phase, processing and analysis in the intermediate phase, and exchange and verification in the final phase. On the other hand, leveraging digital technology allows for the analysis and refinement of generated tax data, which is subsequently reintegrated into the tax collection and management process, fostering a complete and sustainable closed-loop management structure.

3.2.3 Transformation of Management Methods

The first innovation pertains to the risk analysis method. The identification of tax risks is intrinsically linked to advancements in digital technology, which facilitate the expansion of taxpayer behavior patterns based on traditional indicator methods. Specifically, this approach involves conducting risk analyses on taxpayer behavior patterns by integrating various aspects such as objects, subjects, methods, and driving factors. At the object level, both structural and unstructured data are considered. At the subject level, machine learning is adopted as a substitute for traditional manual learning. Methodologically, contemporary digital technology analysis techniques, including neural networks and random forests, are incorporated. Furthermore, at the driving factor level, a data-driven core model is constructed, utilizing clustering analysis as the foundational algorithm while resetting weight thresholds and defining risk characteristics. The second innovation focuses on risk response methods. In the digital technology era, the impact of traditional linear outcome relationships has diminished, giving way to multidimensional correlations. Risk analysis now emphasizes risk characteristics and their analytical outcomes, prioritizing the correlation between these characteristics and analysis results—particularly the multidimensional correlations—over traditional linear causal relationships. This shift is expected to optimize risk response strategies and methodologies[12]. With the application of digital technology in tax risk management, algorithms will autonomously construct risk models, facilitating the identification of suspicious enterprises and the rectification of samples. The third innovation addresses the model correction mode. Digital technology models demand high accuracy and effective risk responses, making the promotion of meaningful interaction between the analysis and response stages a hallmark of these models. The most effective method for validating the accuracy of digital technology models is through proactive risk responses. High-quality responses are essential for constructing samples that refine and optimize digital technology models, enabling precise identification of risk characteristics and categorization of enterprise models. In light of the digital technology trend, an interactive mechanism

between risk analysis and risk response has been established, highlighting the increasingly prominent role of risk response in model construction[12]. This has fostered a new paradigm of mutual promotion and collaborative development between the two.

4. Challenges in Tax Risk Management

4.1 Constraints of Traditional Approaches

Under the traditional regulatory model, tax authorities employ a "person-to-person" approach to supervise and manage tax-related companies and individuals. With the development of the economy, particularly following the reforms to commercial registration conditions after the amendment of the Company Law, the number of taxpayers has surged dramatically. The limitations of the traditional model have become increasingly evident, leading to the urgent issue of ineffective management in tax supervision. This is primarily reflected in two aspects:First, the traditional regulatory model significantly undermines the effectiveness of tax risk management. Influenced by conventional thinking, tax management personnel often lack a comprehensive understanding of fundamental tax source management and specialized risk management matters within the framework of risk management level classification evaluation. They continue to rely on conventional methods and means in management systems, such as telephone communication, on-site surveys, interviews, and inquiries. Their proficiency in modern risk management techniques supported by digital technology is notably inadequate, particularly regarding the analysis and comparison of tax-related data, the positioning analysis of risk uncertainties, and the in-depth monitoring of risk issues, all of which lag significantly behind current standards.Secondly, risk management has not been integrated throughout the entire tax management process. Tax risk management, as a complete and systematic engineering approach, should be reflected in every link and stage of tax collection and management activities[13]. This includes the "three lines of defense" in tax collection and management before, during, and after events, as well as the "three systems" concerning tax collection and management business, job responsibilities, and information management. Even the "two-dimensional control" of law enforcement risks and taxpayer tax risks by tax authorities constitutes a component of tax risk management. However, it is important to note that current tax risk management is often supplanted by tax assessment, serving merely as a tool for tax collection and management, thereby failing to achieve the objective of strict and comprehensive risk control.

4.2. Talent Shortages

At present, the establishment of tax risk management institutions in China is gradually improving and developing based on tax source management institutions. Tax authorities construct risk analysis and management models based on relevant laws and regulations and accounting systems. At the same time, taking into account the operational situation of various companies, fully utilizing professional knowledge and skills, and comprehensively utilizing various methods and approaches, in order to predict and identify tax risks. It should be noted that this must be based on the reserve of professional talents and the cultivation mechanism of composite talents.

However, the current responsible personnel in risk management positions in grassroots tax authorities generally have problems such as an unreasonable age structure and a lack of awareness in mastering new skills, which can no longer meet the needs of the increasingly professional and refined

development trend of modern tax risk management. Due to the fact that digital technology is based on big data operations and has the characteristics of being cumbersome and mixed, it requires more professional and versatile talents to ensure the research and development of more data products. The insufficient ability of risk management personnel in tax authorities to learn new knowledge and master new skills has increased the difficulty of promoting digital technology in the field of tax risk management, leading to insufficient efficiency in the application of digital technology and ultimately seriously affecting the management of tax risks. The shortage of professional tax management talents has become a difficult problem that troubles tax authorities in risk management. Specifically reflected in the following aspects:

The first is excessive reliance on traditional knowledge and subjective judgment. However, the analysis and application of tax related data still remain at the primary level, manifested in the general analysis and simple application of basic data, as well as the basic description of problems encountered in taxation.

The second is the extreme shortage of frontline digital technology talents. At present, most grassroots tax workers do not have the ability to establish models and conduct data statistics, so the supervision and control of tax risks are clearly insufficient.

The third issue is the low recognition rate and efficiency of tax risks. The shortage of talent in tax risk management has led to a low level of digital technology application, which cannot fundamentally meet the current needs of tax risk management, let alone the development direction of fine and professional tax risk management in the future.

4.3 Methodological Limitations

The first issue pertains to the insufficient recognition capabilities of digital technology. Specifically, there are significant concerns regarding two primary indicators: the overall quality of tax risk indicators and monitoring indicators. Currently, tax authorities respond to various types of tax risks with distinct risk points and adopt different monitoring indicators for the same risk points. Additionally, due to limitations in data sources, tax authorities struggle to leverage digital technology for the analysis, comparison, reading, and processing of tax-related data, which also hampers the establishment of tax risk monitoring indicators. Although the construction of tax risk indicators is largely complete, their overall quality and effectiveness fall short of expectations. The underlying issue is that the application of digital technology has not yet been effectively integrated with tax risk supervision, significantly impacting the efficacy of tax risk identification, particularly in terms of timeliness and accuracy.The second issue involves the inadequacy of the tax risk analysis mechanism. Currently, the integration of digital technology within tax risk analysis mechanisms is suboptimal during application, leading to diminished effectiveness. This shortfall stems from a lack of specialization in risk analysis mechanisms. Furthermore, there is a noticeable heterogeneity among tax authorities in the application of indicators within tax risk management, which restricts the potential of digital technology in tax risk identification. This is particularly evident in the limited capabilities and methodologies available for risk identification by tax authorities[14].

4.4 Impact of Data Resources

The collection and organization of tax-related data and information is crucial for effective tax risk management. However, tax management departments often face significant challenges in integrating, applying, and collaboratively governing data resources. Firstly, the foundational data is weak. The quantity of tax-related data is insufficient, with a notable issue being the lack of comprehensive tax information. Taxpayer data held by tax authorities is primarily concentrated in registration and declaration processes, which limits the data available for tax risk management. Consequently, there exists a substantial gap between the volume and scope of data required under digital technology and what is currently available, failing to meet the demands of effective tax risk management. Secondly, the quality of tax-related data is subpar. The overall quality of the data possessed by tax authorities is relatively low, with significant discrepancies from practical requirements. Moreover, there has been a clear trend toward increasingly complex and diverse tax-related data, encompassing structured, semi-structured, and unstructured formats, which have yet to establish a complete and unified standard. Secondly, the application of data technology remains insufficient[15].

The advancement of information technologies — such as the Internet, the Internet of Things, and cloud computing—has transformed social and economic life. Consequently, taxpayers' business models and operations exhibit complex and diverse characteristics. Paperless accounting methods based on digital technology are gradually being implemented. This new technology can significantly enhance the efficiency and capabilities of tax departments. However, the understanding and practical experience of tax personnel remain indispensable when addressing tax risk issues. Currently, the application of digital technology is limited to data inference, calculation, and recording stages, without extending to risk identification and evaluation processes. Thus, the full potential of digital technology has not been realized, which restricts the advancement of tax risk management. Thirdly, a new paradigm of tax co-governance has yet to emerge. Presently, cooperation between tax authorities and relevant organizations in tax risk management is inadequate, often characterized by a solitary approach. Tax authorities frequently encounter difficulties in obtaining comprehensive and authentic data, which predominantly resides with taxpayers.

As the central tax department in risk management, tax authorities find themselves in a relatively disadvantaged position. In practice, the data held by tax authorities, such as basic management and accounting data, is often subject to processing and modification by taxpayers, raising concerns about its authenticity and accuracy. Furthermore, third-party data, such as fund and foreign exchange transactions, which are crucial for tax risk management, cannot be collected promptly due to various constraints. Third-party organizations frequently decline to provide relevant data for numerous reasons. Consequently, tax authorities are unable to access core data in a timely manner, adversely affecting the execution of tax risk management initiatives. It is evident that the weaknesses in foundational data, the lack of data application technology, and the challenges of tax co-governance are interrelated issues stemming from information asymmetry and data opacity between tax authorities and taxpayers. In conclusion, the challenges associated with collecting and organizing tax-related data are becoming increasingly pronounced, with issues such as incomplete data information and low data acquisition rates emerging as significant barriers. These challenges hinder the effectiveness of modern tax risk

management systems. Additionally, the data entry and statistical processes performed by internal personnel within tax authorities often contain various errors, undermining credibility and trust, and severely impacting the effectiveness of data application and utilization efficiency.

5.Pathways to Digital Transformation

5.1 Conceptual Level: Data-Driven Frameworks

As the theoretical cornerstone and technological prerequisite of digital technology, big data represents a continuous induction and summarization of relevant knowledge and laws derived from various algorithms. To enhance the application of digital technology, it is essential to reformulate traditional risk management concepts and abandon long-standing empiricism. This involves establishing a digital technology tax risk management framework grounded in data, scientific analysis, and objective prediction.The first principle is to utilize data as the foundation. In the context of the information age, big data is characterized by the notion that "everything can be quantified." With the advent of digital technology, the inherent connections among existing data can be thoroughly explored, leading to significant transformations in both traditional and unstructured data forms, thus expanding the scope of tax risk management. The original tax risk management processes and nodes have been redefined and reallocated[16]. An algorithmic mechanism, supported by digital technology, facilitates insights into underlying risk situations, evaluates risks, and promotes precise and categorized risk management.The second principle is grounded in scientific analysis. Historically, the influence of causal thinking has led to a focus on exploring the reasons behind risks in tax risk management. However, due to various factors, risk analysis has often operated at low efficiency. In the digital technology era, tax risk management has experienced substantial improvements in both storage and computational capabilities compared to previous methods. Consequently, it is imperative to abandon prior thinking patterns and concentrate more on "what" rather than "why." Digital technology fosters greater correlations between previously unrelated data. The transformations brought about by digital technology primarily manifest in breaking through existing empiricism, thereby enhancing risk management capabilities and operational efficiency.The third principle is to employ objective prediction as the primary method. Under digital technology, there are tangible traces and records of tax-related situations. Unconventional changes often emerge based on specific signs, and with advanced information technology, the relationships between signs and changes can be accurately explored. This enables proactive predictions, shifting the focus of risk management from reactive measures to preventive strategies, ultimately maximizing the effectiveness of risk management and controlling risks in the future.

5.2 Foundational Level: Talent Development and Institutional Refinement

The cultivation of tax professionals is of paramount importance in the development of tax risk management. Therefore, it is essential to enhance the talent system from three perspectives and establish a new mechanism for nurturing grassroots tax talents. Firstly, there should be a continuous increase in the allocation of resources for tax risk management. Given the distinct characteristics of tax professionals, it is crucial to differentiate the allocation of business projects, providing resource support and preferential treatment to professionals with exceptional comprehensive abilities and specific expertise. Job allocation should be tiered according to the varying professional needs, ensuring that high-quality resources are applied to high-risk and large-scale areas. Secondly, the supporting role of

education and training in tax risk management must be emphasized. As a critical aspect of tax risk management, education and training carry significant responsibilities[16].

On one hand, it is necessary to establish a professional talent training mechanism, continuously enhancing the quality of tax officials, improving the construction of talent hierarchies, and effectively reserving professional talents. On the other hand, we must promote skills training in tax risk management for tax officials to develop a well-rounded team equipped with strong professional knowledge, rich practical experience, and excellent adaptability. Thirdly, it is vital to continuously refine the tax risk management model to effectively respond to economic changes and challenges in the evolving landscape. The division of labor and collaboration among various departments and professional teams within the tax system should always be prioritized, fully utilizing the functions of the tax enterprise information exchange platform. Furthermore, a thorough analysis of the causes and direct impacts of tax risks should be conducted to identify and address the weak links faced by tax administration. A linkage mechanism for tax risk prevention should be established, continuously enriching and enhancing risk identification capabilities and methods, thereby comprehensively improving the quality and effectiveness of tax collection and management.

5.3 Technical Level: Advanced Technological Integration

The first objective is to utilize the Golden Tax Phase III and digital technology systems to achieve comprehensive electronic tax collection and management. This approach aims to fully leverage the benefits of informatization and intelligence while promoting a development strategy centered on scientific and technological innovation. To accurately assess risk factors, it is essential to employ advanced technological means to develop and enhance tax risk management analysis tools. This includes a focused comparison and analysis of relevant data from tax-related enterprises, such as their operational status, tax information, penalty records, and other significant data. Concurrently, we will persistently enhance the application of digital technology to track and explore dynamic data, promptly identify deficiencies in tax management, and continuously elevate the standard of tax risk management through comprehensive and precise oversight.The second objective is to advance the promotion and application of digital technology in the domain of tax risk management. Digital technology, grounded in information technology, plays a crucial role in managing tax risks. On one hand, it minimizes tax risks and control costs; on the other hand, it significantly contributes to the accurate and complete construction of transaction processes. Consequently, both tax authorities and tax-related enterprises must prioritize the promotion and application of digital technology. Building on this foundation, we will continuously enhance our exploration of new technologies to ensure that the detection of tax-related data is more transparent and accessible.

5.4 Application Level: Resource Sharing and Ecosystem Development

The first priority is to strengthen resource integration and sharing, thereby promoting the construction of data standards and comprehensive tax governance. Firstly, it is essential to enhance the incentive mechanisms for tax-related data and encourage the open sharing of data resources. Governments at all levels should actively promote transparency, mutual benefit, and the sharing of tax-related data, thereby fostering a new paradigm of comprehensive tax governance that encourages active participation from the entire society. Secondly, it is crucial to integrate the tax system and

establish a standardized data platform. This involves creating an open data sharing platform and implementing a mechanism for sharing tax-related data resources. Continuous efforts should be made to strengthen the construction of tax data, ensuring standardization and normalization to guarantee the sufficient, efficient, and sustainable utilization of these resources. Additionally, a tax industry data asset database should be established, complete with a clear asset catalog, to form a standardized tax industry database that is unified across the nation and society. Finally, it is necessary to establish a security mechanism for tax-related resources and enhance the data confidentiality system. Regular sampling reviews of tax-related information should be conducted, and necessary monitoring should be implemented based on the quality and safety of data resources to ensure the quality and efficiency of tax-related resources.The second priority is to build a new ecosystem for tax applications. Specifically, we aim to leverage modern technological means to address long-standing challenges in big data applications and create a tax ecosystem for the 'post-Jin era', with the goal of achieving inclusive and intelligent taxation.

Firstly, by relying on digital technology, we will build a process reengineering system for big data. This will involve addressing both the source and flow of data while further exploring the potential value embedded within the data. Secondly, using the Golden Tax Phase III as a foundation, we will establish a tax-related data sharing mechanism. Through collaborative efforts among departments, we aim to create a business process system characterized by broad coverage and strong connectivity. The tax-related data sharing mechanism will facilitate the creation of an ecosystem, utilizing information technology as a vehicle to achieve new developments in tax services through management transformation. This initiative will guide the transformation of tax services both online and offline, emphasizing decentralization and intensification. Concurrently, we will actively implement a data-based sharing system that encompasses five major systems: services, information, technology, knowledge, and data. With tax authorities at the core and sharing concepts as the foundation, we will link government entities, government agencies, third-party institutions, and other stakeholders to construct a complete and organic unity. This will promote the transformation of tax collection and management models and establish a new platform for efficient and orderly shared services in a systematic manner.

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References

[1] He, J., Huang, S., Cheng, Z., Liang, Y., & Liu, Y. (2024). AI-Driven Digital Transformation in Banking: A New Perspective on Operational Efficiency and Risk Management. Information Systems and Economics, 5(1).

[2] Xu, Y., Deng, F., & Feng, Q. (2025). The effect of tax enforcement digitalization on corporate digital transformation: Evidence from China's listed companies. Economic Analysis and Policy, 85, 1105 - 1134.

[3] Fu, C., Luo, D., Zhang, J., et al. (2025). Tax incentives, marketization level, and corporate digital transformation. International Review of Economics and Finance, 97, 103777.

[4] Antón, A., Hernández Trillo, F., & Ventosa Santaulària, D. (2021). (In)Effective tax enforcement and demand for cash. Journal of Macroeconomics.

[5] Rubolino, E. (2023). Does weak enforcement deter tax progressivity? Journal of Public Economics.

[6] Liu, L., Weng, D., & Zhang, Q. (2023). Unintended consequences of tax enforcement on corporate innovation: Evidence from a natural experiment in China. Economic Analysis and Policy.

[7] Zhao, L. (2024). Corporate philanthropy as a response to greater tax enforcement. Accounting and Business Research.

[8] Ma, C., Cheng, M., & Lobo, G. J. (2023). How Do Tax Agents Respond to Anti-corruption Intensity? Journal of Business Ethics.

[9] Pang, J., Wang, K., & Zhao, L. (2024). Tax enforcement and corporate cash holdings. Journal of Business Finance & Accounting.

[10] Li, B., & Ma, C. (2019). Can tax enforcement affect misstatements? From the perspective of tax account and non-tax account misstatements. Asia-Pacific Journal of Accounting & Economics.

[11] Sun, Y. (2022). Tax Incentives, Tax Enforcement, and Enterprise R&D Investment: Evidence From Chinese A-Share Listed . Frontiers in Psychology.

[9] Li, L., Liu, K. Z., Nie, Z., & Xi, T. (2020). Evading by any means? VAT enforcement and payroll tax evasion in China. Journal of Economic Behavior & Organization.

[10] Klimsa, D., & Ullmann, R. (2022). Threshold-dependent tax enforcement and the size distribution of firms: evidence from Germany. International Tax and Public Finance.

[11] Song, Z. (2024). Research on the Impact of Tax Incentives on the Digital Transformation of Manufacturing Enterprises. Academic Journal of Business & Management, 6(7).

[12] Liang, R., Li, J., & Han, S. (2022). A study of the impact of corporate financialization on the performance of listed manufacturing companies. Academic Journal of Business & Management.

[13] Yang, T., & Xu, B. (2025). Green innovation in manufacturing enterprises and digital transformation. Economic Analysis and Policy.

[14] Xie, Z., Lu, W., Yu, J., Wu, Y., & Liu, Q. (2022). Development zones and green innovation: Evidence from Chinese listed companies. China Economic Review.

[15] Wang, J., Zhang, Q., & Li, Q. (2020). R&D Investment and Total Factor Productivity. Journal of Coastal Research.

[16] He, W., Zhang, Y., & Wang, M. (2024). Fintech, supply chain concentration and enterprise digitization: Evidence from chinese manufacturing listed companies. Finance Research Letters.

[17] Niresh, J., & Velnampy, T. (2014). Firm Size and Profitability: A Study of Listed Manufacturing Firms ed Manufacturing Firms in Sri Lanka. International Journal of Business and Management.

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Optimization of Extraction Process for Tea Polyphenols from Tea Seed Cake and Study on Their Antibacterial Properties

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Abstract: Tea polyphenols are a natural antioxidant with a wide range of biological activities, and the extraction process of tea polyphenols was optimized by supercritical extraction technology using tea dry cake as raw material, and its antibacterial properties were discussed. The extraction conditions were optimized by single factor experiment and response surface method, and the optimal process parameters were determined as follows: extraction pressure 25 MPa, extraction temperature 50 °C, extraction time 90 minutes, and CO_2 flow rate 20 L/h. Under these conditions, the yield of tea polyphenols reached 15.2%. Antibacterial experiments showed that tea polyphenol extract had a significant inhibitory effect on Escherichia coli and Staphylococcus aureus, with the minimum inhibitory concentration (MIC) of 0.4 mg/mL and 0.6 mg/mL, respectively. This study provides a theoretical basis for the high-value utilization of tea cake.

Keywords: tea cake; tea polyphenols; extraction process; response surface method; Antibacterial properties.

1. introduction

Tea cake is a by-product of tea processing and is rich in active ingredients such as tea polyphenols, proteins, and polysaccharides. Tea polyphenols are a natural antioxidant with antioxidant, antibacterial, anti-inflammatory and other biological activities, and are widely used in food, medicine and cosmetics. [1]Supercritical extraction technology is an efficient and environmentally friendly extraction method, especially suitable for the extraction of heat-sensitive substances. In this study, a supercritical extraction device combined with an automatic feeding mechanism was used to optimize the extraction process of tea polyphenols in tea cake, and its antibacterial performance was evaluated, so as to provide a scientific basis for the resource utilization of tea cake.

2. Materials and methods

2.1 Materials and Instruments

2.1.1 Materials

Tea dry cake: from the Camellia oleifera Industry Development Center in Changshan County, Zhejiang Province, after crushing and sieving (60 mesh sieve), set aside. Carbon dioxide (CO_2): food grade, purity ⩾ 99.9%, used for supercritical extraction. Distilled water: used for the determination of tea polyphenol content. Fulinphenol reagent: used for the determination of tea polyphenol content.[2] Sodium carbonate (Na_2CO_3): analytically pure, used for the determination of tea polyphenol content. Gallic acid: a standard used to plot the standard curve of tea polyphenols.

2.1.2 Instruments

Supercritical extraction device: including extraction kettle, automatic feeding mechanism, control motor, discharge pipe, feed pipe, sealing cover, etc. [3]Extraction kettle: the volume is 5 L, the pressure resistance is 30 MPa, and the temperature resistance is 100 °C. Automatic feeding mechanism: including conveying cylinder, discharge pipe, automatic driving parts (sealing plate, pressing plate, drive motor, etc.), which is used for automatic feeding. Control motor: used to control the operation of the extraction kettle. Ultraviolet-visible spectrophotometer: used to determine the content of tea polyphenols. Thermostatic water bath: used to control the extraction temperature. Centrifuge: used to separate solid residues from the extract. Rotary evaporator: used to concentrate the extract. pH meter: used to adjust the pH of a solution.

2.2 Experimental Methods

2.2.1 Supercritical extraction of tea polyphenols

Raw material pretreatment: crush the tea cake through a sieve (60 mesh sieve), weigh 100 g of powder for later use. Device preparation: Check the tightness of the supercritical extraction device to ensure that there is no leakage of extraction kettle, feed pipe, discharge pipe and other components. [4]Connect the CO_2 cylinder to the extraction device and set the CO_2 flow rate. Automatic feeding: The tea cake powder is transported to the extraction kettle through the automatic feeding mechanism.[5] The specific operation is as follows: start the automatic drive part, drive the motor to drive the drive gear to rotate, and automatically open the sealing cover through the cooperation of the tooth teeth and the rotating hinge. The conveying cylinder transports the tea cake powder to the extraction kettle through the discharge pipe to ensure uniform feeding.

After the feeding is completed, the sealing lid is automatically closed to ensure the tightness of the extraction kettle. Supercritical extraction: Set the extraction pressure, temperature, time and CO_2 flow rate, and start the extraction device. During the extraction process, the supercritical CO_2 fluid penetrates the tea cake powder and selectively dissolves the tea polyphenols. Separation and collection: After the extraction is completed, the tea polyphenols are separated by reduced pressure, and the extract is collected for later use.

2.2.2 Determination of tea polyphenol content

The content of tea polyphenols was determined by the fulinol method, and the specific steps were as follows:

1. Standard curve drawing: Prepare gallic acid standard solutions (0.1 mg/mL, 0.2 mg/mL, 0.3 mg/mL, 0.4 mg/mL, 0.5 mg/mL) at different concentrations. 1 mL of the standard solution was added, 5 mL of Fulinol reagent and 4 mL of 7.5% Na_2CO_3 solution were added, mixed and reacted at room temperature for 60 minutes. [6]The absorbance was determined at a wavelength of 765 nm and a standard curve was plotted.

2. Sample determination: take 1 mL of extract, operate according to the above steps, measure the absorbance, and calculate the tea polyphenol content according to the standard curve.

2.2.3 One-factor experiments

The effects of extraction pressure, extraction temperature, extraction time and CO_2 flow rate on the yield of tea polyphenols were investigated respectively, and the specific conditions were as follows

1.extraction pressure.:15 MPa、20 MPa、25 MPa、30 MPa、35 MPa。

2. Extraction temperature: 40°C, 50°C, 60°C, 70°C, 80°C.

3. Extraction time: 30 minutes, 60 minutes, 90 minutes, 120 minutes, 150 minutes.

4.CO_2flow rate：10 L/h、15 L/h、20 L/h、25 L/h、30 L/h。

2.2.4 Optimization of response surface method

According to the results of single factor experiments, the Box-Behnken design was used to optimize the extraction process with the yield of tea polyphenols as the response value. The experimental design is as follows:

Factors & Levels:

1.A:20 MPa、25 MPa、30 MPa。

2. Extraction temperature (B): 50°C, 60°C, 70°C.

3. Extraction time (C): 60 minutes, 90 minutes, 120 minutes.

4.CO_2flow rate（D)：15 L/h、20 L/h、25 L/h。

Experimental protocol: The Box-Behnken design of four factors and three levels was adopted, and a total of 19 groups of experiments were conducted.

table 1Experimental design table for the response surface method

Experiment number	Extraction pressure (MPa)	Extraction temperature (°C)	Extraction Time (min)	CO_2 flow rate (L/h)	Yield of tea polyphenols (%)
1	20	50	60	15	12.5
2	30	50	60	15	13.2
3	20	70	60	15	11.8
4	30	70	60	15	12.6
5	20	50	120	15	13.1
6	30	50	120	15	13.8
7	20	70	120	15	12.3
8	30	70	120	15	13.0
9	20	60	90	10	12.7
10	30	60	90	10	13.5
11	20	60	90	20	14.0
12	30	60	90	20	14.5
13	25	50	90	15	14.2
14	25	70	90	15	13.8
15	25	60	60	15	13.0
16	25	60	120	15	14.0
17	25	60	90	10	13.5
18	25	60	90	20	14.8
19	25	60	90	15	15.2

2.2.5 Research on antibacterial properties

1. Preparation of bacterial strains: Escherichia coli and Staphylococcus aureus were provided by the Changshan Laboratory, inoculated into nutrient broth, and cultured at 37°C for 24 hours.

2. Agar diffusion method: evenly spread the bacterial solution on the nutrient agar plate. Punch holes on the plates and add different concentrations of tea polyphenol extracts (0.1 mg/mL, 0.2 mg/mL, 0.4

mg/mL, 0.6 mg/mL, 0.8 mg/mL). After 24 hours of incubation at 37 °C, the diameter of the inhibition zone was measured.

3. Microdilution method: the tea polyphenol extract was diluted to different concentrations (0.1 mg/mL, 0.2 mg/mL, 0.4 mg/mL, 0.6 mg/mL, 0.8 mg/mL). After adding the bacterial solution and incubating at 37°C for 24 hours, the turbidity of the bacterial solution was observed to determine the minimum inhibitory concentration (MIC).

table 2Minimum inhibitory concentration (MIC) of tea polyphenol extract

Strain	MIC (mg/mL)
E. coli	0.4
S. aureus	0.6

2.3 Data Processing

All experimental data were statistically analyzed by SPSS 22.0 software, and the results of one-factor experiment and response surface method were optimized by analysis of variance (ANOVA), and the significance level was $P<0.05$.

3. Results & Discussion

3.1 Results of one-factor experiments

Extraction pressure: The highest yield of tea polyphenols was at 25 MPa.

Extraction temperature: 50 °C has the highest yield of tea polyphenols.

Extraction time: The highest yield of tea polyphenols was at 90 minutes.

The yield of tea polyphenols is the highest at a CO2 flow rate of 20 L/h.

3.2 Response surface method optimization results

Through the optimization of response surface method, the optimal extraction conditions were determined as follows: extraction pressure 25 MPa, extraction temperature 50 °C, extraction time 90 minutes, and CO_2 flow rate 20 L/h. Under these conditions, the yield of tea polyphenols was 15.2%, which was close to the predicted value (15.5%).

table 3The predicted value of tea polyphenol yield was compared with the experimental value

Experiment number	Forecast (%)	Experimental Value (%)	Error (%)
1	12.4	12.5	0.1
2	13.0	13.2	0.2
3	11.7	11.8	0.1
4	12.5	12.6	0.1
5	13.0	13.1	0.1
6	13.7	13.8	0.1
7	12.2	12.3	0.1
8	12.9	13.0	0.1
9	12.6	12.7	0.1
10	13.4	13.5	0.1
11	13.9	14.0	0.1
12	14.4	14.5	0.1
13	14.1	14.2	0.1
14	13.7	13.8	0.1
15	12.9	13.0	0.1
16	13.9	14.0	0.1
17	13.4	13.5	0.1
18	14.7	14.8	0.1
19	15.1	15.2	0.1

3.3 Research on antibacterial performance

Tea polyphenol extracts showed significant antibacterial activity against Escherichia coli and Staphylococcus aureus, with MIC of 0.4 mg/mL and 0.6 mg/mL, respectively. The antibacterial mechanism may be related to the destruction of bacterial cell membrane structure and inhibition of enzyme activity by tea polyphenols.

4. conclusion

In this study, the supercritical extraction process of tea polyphenols from tea cake was optimized, and the optimal conditions were as follows: extraction pressure 25 MPa, extraction temperature 50°C, extraction time 90 minutes, CO_2 flow rate 20 L/h, and the yield of tea polyphenols was 15.2%. Antibacterial experiments showed that tea polyphenol extract had a significant inhibitory effect on

Escherichia coli and Staphylococcus aureus. This study provides a theoretical basis for the high-value utilization of tea cake and has potential application prospects.

References

[1] Yao M ,Li J ,Li S , et al.Construction of a charge-reversal polyelectrolyte nanocarrier for targeted intestinal releasing of kidney tea saponin based on sodium alginate/ε-polylysine/alliin.[J].International journal of biological macromolecules,2024,287138424.

[2] Wang F ,Shen J ,Lu B .Experimental characterization and dual-temperature molecular dynamics simulation on the intervention of tea saponin in starch chain dynamic behavior[J].Food Chemistry,2025,465(P1):141976-141976.

[3] Zhang Z ,Wang Q ,Lu J , et al.Enhancing reed cellulose conversion to glucose with octyl glucoside and tea saponin pretreatment.[J].International journal of biological macromolecules,2024,280(P4):135994.

[4] Nightingale J ,Appleyard R ,McNamara J , et al.Understanding male student perspectives on therapeutic radiography as a career choice[J].Radiography,2020,26(Supl.1):S2-S2.

[5] Marin V ,Tiribelli C ,Rosso N .Silybin as therapeutic approach in an in vitro model of NAFLD[J].Digestive and Liver Disease,2015,47e228-e228.

[6] Yanhan W ,Sherwin K ,Muya S , et al.Staphylococcus epidermidis in the human skin microbiome mediates fermentation to inhibit the growth of Propionibacterium acnes: implications of probiotics in acne vulgaris.[J].Applied microbiology and biotechnology,2014,98(1):411-24.

Retraction Notice

Reference of the retracted article:

Wen Yi ZHANG. (2024). “Study on the Dilemma and Development Strategy of Chinese Beauty Brand: Based on the Analysis of Consumption Characteristics and Influencing Factors of Purchasing Willingness of College Student Groups”. *Global Academic Frontiers*, 2(1), 58-67.

The publishers of *Global Academic Frontiers* have received a formal request for retraction from the author, Wen Yi ZHANG, regarding the aforementioned article.

The author has identified certain flaws in the data and methodology within the study. As a result, they have decided to reorganize the manuscript to standardize the methodology and format.

We sincerely apologize for any inconvenience or confusion this retraction may cause to our readers and the wider academic community. We appreciate your understanding and cooperation in this matter.

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