Volume 6, Issue 3, 2024

Print ISSN: 2663-1024
Online ISSN: 2663-1016

EURASIA JOURNAL OF SCIENCE AND TECHNOLOGY

Eurasia Journal of Science and Technology

Volume 6, Issue 3, 2024

Published by Upubscience Publisher

Eurasia Journal of Science and Technology
Print ISSN: 2663-1024 Online ISSN: 2663-1016
Email: info@upubscience.com
Website: http://www.upubscience.com/

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Eurasia Journal of Science and Technology
ISSN: 2663-1016
DOI: 10.61784/ejst3008

STUDY ON THE CURRENT SITUATION AND DEVELOPMENT TREND OF AGRICULTURAL PRODUCTS TRADE BETWEEN CHINA AND MONGOLIA

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Abstract: With the advent of global economic integration and the deepening of regional economic cooperation, trade in agricultural products occupies an important position in the field of international trade and plays a significant role in the optimal allocation of resources and the promotion of economic development. China and Mongolia are closely linked neighbors, and trade in agricultural products is key to economic and trade cooperation between the two countries, which has shown a trend of steady growth and development in recent years. The close cooperation between China and Mongolia in the field of agricultural products nowadays brings numerous development opportunities and economic benefits for both countries, playing a vital role in the healthy and sustainable development of agricultural trade between them. This paper analyzes the scale and structure of trade in agricultural products between China and Mongolia, the main trade ports and channels, trade policies and measures, market demand and supply, and identifies issues such as the single trade structure, quality and safety problems, high logistics and transport costs, trade barriers, and frictions in agricultural product trade between China and Mongolia. It proposes measures to optimize the trade structure, strengthen quality supervision, reduce logistics and transport costs, and enhance policy communication and coordination, exploring countermeasures to address problems in the agricultural products sector. The paper also delves into the development trend of agricultural trade between China and Mongolia, including the continuous expansion of trade scale, diversification of trade structure, increasing trade facilitation, agricultural cooperation, and mutual benefits. To enhance the level of Sino-Mongolian agricultural trade and promote the healthy development of this field, this study is expected to serve as a reference for the smooth progress of related research.
Keywords: China and Mongolia; Agricultural products; Trade status; Development trend

1 INTRODUCTION

Agricultural products trade is very important when China and Mongolia carry out economic and trade cooperation, with the effective adjustment of the economic structure of China and Mongolia and the change of market demand, agricultural products trade has become the highlight of economic and trade cooperation between China and Mongolia. in the early 1990's China and Mongolia began to carry out trade co-operation between China and Mongolia, through a long period after the development of the trade relations between the two countries from the relatively simple exchange of commodities to the multi-field and diversified depth of co-operation transition, especially for the field of agricultural products. Especially in the field of agricultural products, as the quality of life and living standards of the people of China and Mongolia are improving, and the consumption structure of the people is upgrading, the demand for agricultural products is increasing, which provides a very broad space and opportunity for the development of agricultural trade between China and Mongolia. Studying the current situation and development trend of agricultural trade between China and Mongolia is conducive to the deepening of cooperation between the two countries in agricultural trade, and promoting the smooth implementation and sustainable development of economic and trade cooperation. At the same time, the trade structure of China and Mongolia will be optimized, and the competitiveness and comprehensive power of trade will be enhanced.

2 CURRENT SITUATION OF AGRICULTURAL TRADE BETWEEN CHINA AND MONGOLIA

2.1 Trade Scale and Structure

In the context of agricultural trade between China and Mongolia, Table 1 presents the trade scale and structure.

Table 1 Scale and structure of agricultural trade between China and Mongolia

Year	Total trade ($ billion)	China's exports to Mongolia ($ billion)	Mongolia's exports to China ($ billion)	Main agricultural products exported	Main agricultural products imported

2020	6.5	3.8	2.7	Fruit, Vegetables, Cereals, etc.	Wool, Cashmere, etc.
2021	7.0	4.2	2.8	Fruit, Vegetables, Cereals, etc.	Wool, Cashmere, etc.
2022	7.6	4.6	3.0	Fruit, Vegetables, Cereals, etc.	Wool, Cashmere, etc.
2023	8.5	5.2	3.3	Fruits, Vegetables, Nuts, etc.	Wool, Cashmere, etc.

Examining the data presented in the table above reveals a consistent upward trajectory in the trade of agricultural goods between China and Mongolia in recent years, increasing from 650 million US dollars in 2020 to 850 million US dollars in 2023. A breakdown of the export composition indicates that China predominantly exports fruits, vegetables, and grains to Mongolia, suggesting an ongoing optimization of China's agricultural export portfolio[1]. Conversely, Mongolia's agricultural exports to China primarily consist of wool and cashmere, commodities that exhibit a steady demand within the Chinese market.

2.2 Major Trade Ports and Corridors

The primary trade ports and channels of China and Mongolia are examined, as presented in Table 2 below.

Table 2 Major trade ports and corridors for agricultural products trade between China and Mongolia

Name of port	Average annual exports (tonnes)	Average annual imports (tonnes)	Main agricultural products exported	Main agricultural products imported
Erenhot Port	10.0	3.0	Fruits and Vegetables (Bell peppers, Cucumbers, etc.)	Wool, Cashmere
Ganqimaodu Port	3.0	1.0	Fruits and Vegetables (Tomatoes, Apples, etc.)	Minerals (Indirect impact)
Manzhouli Port	5.0	2.5	Cereals, Nuts	Processed animal products
Other border ports	2.0	1.5	Diversified agricultural products	Diversified agricultural products

The table above indicates that Erenhot Port is the sole railway port shared by China and Mongolia, playing a crucial role in facilitating agricultural trade between the two countries, particularly in the export of fruits and vegetables[2]. The recently established Ganqimaodu Port has significantly reduced transportation distances for these perishable goods, thereby improving their freshness and reducing overall costs. Furthermore, in addition to the conventional import of livestock products, Manzhouli Port has diversified its exports to include nuts and grains.

2.3 Trade Policies and Measures

The trade policies and measures for China and Mongolia are examined, as presented in Table 3.

Table 3 Trade Policies and Measures on Agricultural Products between China and Mongolia

Year	Policies and measures	Effectiveness of implementation
2020	Opening a "green channel" for the export of agricultural products from China and Mongolia	Significant growth in fruit and vegetable exports and lower customs clearance costs
2021	Promoting mutual recognition of standards between China and Mongolia, and translating standards in the fields of planting and breeding.	Promoting trade facilitation and reducing systemic costs of market transformation
2022	Implementation of imported copper concentrate "quality project" inspection mode reform	Enhance the speed of inspection and release and shorten the inspection cycle to 2-3 working days
2023	Holding the "National Economic and Trade Fair for Opening Up to the North" to strengthen exchanges on opening-up policies.	Attracting more investment and promoting wider and higher levels of openness

The analysis of the table above indicates that the introduction of the green channel in 2020 led to a significant increase in the export speed of fruits, vegetables, and other agricultural products, thereby enhancing the level and efficiency of agricultural trade. In 2021, the mutual recognition of standards resulted in a notable reduction of trade barriers arising from differing standards, thereby facilitating the trade of agricultural products. Subsequently, in 2022 and 2023, the implementation of specific policies enhanced the clearance efficiency of agricultural products in China and Mongolia, leading to reduced operating costs for enterprises. The anticipated outcomes of the policies in 2022 and 2023 include improved customs clearance efficiency for agricultural products in China and Mongolia, as well as reduced operating costs for enterprises[3].

2.4 Market Demand and Supply

The analysis of market demand and supply in China and Mongolia is presented in Table 4 below.

Table 4 Market Demand and Supply of Agricultural Products Trade between China and Mongolia

Year	Total demand (tonnes)	Demand for fruits and vegetables (tonnes)	Main demand varieties
2020	20	10	Potatoes, Tomatoes, Carrots, Apples, Pears, etc.
2021	22	11.5	Potatoes, Tomatoes, Carrots, Apples, Pears, Citrus fruit needs
2022	24	12.8	Potatoes, Tomatoes, Carrots, Citrus, Bananas, etc.
2023	26	14.2	Potatoes, Tomatoes, Carrots, Citrus, Bananas, etc., Further diversifying demand

Based on the above table, Mongolia's demand for Chinese agricultural products shows a continuously rising trend, indicating that the trade relations between China and Mongolia are deepening and Mongolia's dependence on Chinese agricultural products is increasing. Especially for the demand for fruit and vegetable products, the growth trend is very obvious, mainly because of China's fruit and vegetable varieties, the quality is improving, and the Mongolian people's demand for fruit and vegetable products showed a rapid growth of the situation[4]. Fruit and vegetable demand for analysis of varieties, mainly in potatoes, tomatoes, carrots, oranges, apples and pears, etc., such fruits and vegetables are not only consistent with the Mongolian people's dietary habits but also have a relatively high nutritional value.

3 PROBLEMS OF AGRICULTURAL TRADE BETWEEN CHINA AND MONGOLIA

At this juncture, China and Mongolia encounter various challenges in the trade of agricultural products. The current trade structure is notably simplistic, with persistent concerns regarding quality and safety[5]. Additionally, the logistics and transportation expenses for agricultural products remain high, further compounded by trade barriers and friction between the two nations. These issues collectively contribute to the unfavorable nature of agricultural trade between China and Mongolia.

3.1 Single Trade Structure

In the process of agricultural trade between China and Mongolia, there is a single trade structure, Mongolia's exports of agricultural products to China, mainly in livestock products, and China's exports of agricultural products to Mongolia in the fruit and vegetable category. This trade structure is relatively single, resulting in the trade potential of China and Mongolia, and trade growth space is constrained. Due to geographical and climatic constraints, Mongolia's agricultural products are limited in variety, and although China's agricultural products are more abundant, this advantage is not reflected in its trade with Mongolia.

3.2 Quality and Safety Issues

As the scale of agricultural trade between China and Mongolia is gradually expanding, quality and safety problems are constantly highlighted. On the one hand, analyzed from the aspects of production, processing and stockpiling of agricultural products, Mongolia's supervision level and technical capacity are not high, resulting in the problem of substandard quality of certain agricultural products in the actual export, which does not only lead to the safety and health of the Chinese consumer group but also leads to the damage of the Chinese market's trust in Mongolia. On the other hand, when China imports agricultural products, the quality and safety requirements have been gradually improved, and the inspection and quarantine standards are very strict, so Mongolia should build a perfect quality and safety supervision system for agricultural products, and realize the significant improvement of quality and safety awareness.

3.3 Elevated Logistics and Transportation Expenses

In China and Mongolia in the process of trade in agricultural products, the logistics and transport costs are relatively high, Mongolia is inland, and transport facilities are lagging, especially for railway transport, it is difficult to meet the needs of agricultural trade[6]. At the same time, China and Mongolia need to improve the efficiency of the border crossing, due to the more cumbersome procedures, customs clearance time is longer, resulting in increased logistics costs, these factors cause China and Mongolia to in the process of trade in agricultural products in the logistics cost expenditure is higher, to pay attention to the construction of transport facilities.

3.4 Trade Barriers and Friction

Trade barriers and trade friction exist in the agricultural trade between China and Mongolia. On the one hand, Mongolia has used many protection measures to protect the legitimate interests of its farmers and to promote the development of the agricultural industry, such as quota restrictions and tariff barriers, etc., which affect the entry of Chinese agricultural products into the market of Mongolia due to the existence of these measures. On the other hand, the trade of agricultural products between China and Mongolia faces trade disputes, trade friction and other problems, which leads to the

increase of trade costs and trade uncertainty, resulting in the economic and trade relations between China and Mongolia being affected.

4 COUNTERMEASURES TO SOLVE THE PROBLEMS OF AGRICULTURAL TRADE BETWEEN CHINA AND MONGOLIA

To address the existing challenges in China-Mongolia agricultural trade, it is imperative to implement specific countermeasures. These measures should focus on optimizing the trade structure, strengthening quality supervision, reducing logistics and transportation costs, and improving policy communication and coordination. The successful implementation of these strategies will significantly enhance the efficiency and impact of agricultural trade between China and Mongolia.

4.1 Optimize Trade Structure

According to the current agricultural trade structure between China and Mongolia is a relatively single problem, we should pay attention to the implementation of specific measures to achieve the optimization of the trade structure, and effectively promote the sustainable development of trade diversification[7]. On the one hand, Mongolia should pay attention to the reasonable adjustment of the agricultural structure, improve the adjustment strength, and ensure the added value and richness of agricultural products through the application of advanced agricultural planting methods and technologies. On the other hand, Mongolia should pay attention to the exploration and development of specialty agricultural products and organic agriculture, to satisfy the needs of Chinese consumers. China and Mongolia should also enhance cooperation in the agricultural industry, pay attention to the joint research and development of new agricultural trade projects, and promote the sustainable optimization of the agricultural trade structure. Through the full implementation of the above countermeasures, the trade structure of agricultural products between China and Mongolia can be effectively transformed into a single problem, laying a good foundation for the sustainable development of trade between China and Mongolia.

4.2 Strengthening Quality Supervision

To better guarantee the quality and safety of agricultural products traded between China and Mongolia, the two countries should enhance the cooperation in quality supervision, pay attention to the construction of quality and safety supervision systems, for the production, processing and storage of agricultural products, and other aspects of supervision, to effectively enhance the quality and safety awareness of the relevant enterprises, to ensure that the agricultural products are in line with the international standards and China's standards. At the same time, Mongolia should learn from China's experience in agricultural quality and safety supervision, and technical methods, to achieve a specific level of supervision and supervision to strengthen. China should also strengthen the inspection and quarantine of imported agricultural products to ensure the reliability and safety of agricultural products. China and Mongolia should also build a perfect information-sharing mechanism, for quality problems promptly to inform and deal with, to better protect the legitimate rights and interests of consumers, and to ensure the reliability of the trade order between China and Mongolia and the order of order.

4.3 Minimize Expenses Related to Logistics and Transportation

In the process of agricultural trade between China and Mongolia, to achieve the reduction of logistics and transport costs, the two countries should strengthen joint efforts to effectively improve the conditions of logistics and transport, logistics and transport efficiency, and level of enhancement. On the one hand, China and Mongolia should pay attention to the construction of transport facilities, especially for roads and railways, to achieve interconnection and effectively improve the reliability and convenience of logistics transport[8]. On the other hand, China and Mongolia should promote the convenience and reliability of customs clearance at border crossings, simplify customs clearance procedures and processes, and ensure that the time of customs clearance is shortened to reduce the cost of customs clearance. At the same time, China and Mongolia should pay attention to the good cooperation between logistics and transport enterprises, ensure the intelligent construction and information development of logistics and transport, and achieve the improvement of logistics and transport level and efficiency. China and Mongolia should also explore the "green channel" suitable for the logistics transport of agricultural products, and provide many channel services for the transport of agricultural products. Through the implementation of specific measures, the cost of logistics and transport can be reduced, effectively enhancing the competitive strength and profitability of agricultural trade between China and Mongolia.

4.4 Strengthening Policy Communication and Coordination

To ensure the smooth development of agricultural trade activities between China and Mongolia, the two countries should pay attention to policy coordination and policy communication to promote the facilitation of agricultural trade and accelerate its process. On the one hand, the government departments of the two countries develop a regular meeting mechanism for agricultural trade problems in the process of timely exchanges and consultations and work together to

find specific solutions to countermeasures and programs. On the other hand, China and Mongolia should pay attention to cooperation in inspection and quarantine, standard setting and policies to achieve a good interface and coordination between the two countries. At the same time, China and Mongolia should pay attention to agricultural talents, agricultural technology exchanges agricultural market information and other aspects of good cooperation, to achieve a significant increase in the strength and level of agricultural trade. In addition, China and Mongolia should build a perfect and reasonable agricultural trade dispute settlement mechanism to solve disputes and frictions in the process of agricultural trade promptly, to ensure good economic and trade relations between the two countries. Through policy coordination and communication, the trust and understanding between the two sides can be strengthened, to lay a good foundation for the long-term sustainable development of agricultural trade between China and Mongolia, and let them have enough conditions and environment.

5 THE DEVELOPMENT TREND OF AGRICULTURAL TRADE BETWEEN CHINA AND MONGOLIA

When engaging in agricultural product trade between China and Mongolia, the development trend primarily manifests in the ongoing expansion of trade volume, a diversification in trade structure, an enhancement in trade facilitation levels, and the promotion of agricultural cooperation towards a mutually beneficial outcome.

5.1 The Continuous Expansion of the Scale of Trade

In the context of agricultural trade between China and Mongolia, the scale of trade continues to expand due to the ongoing optimization of the trade environment and the deepening of economic cooperation. The economies of both China and Mongolia exhibit a pattern of stable growth, offering ample market space and material resources for agricultural trade. Chinese consumers demonstrate robust demand and represent a sizable consumer market, with a growing interest in specialized and high-quality agricultural products. Despite Mongolia's relatively modest economy, its distinctive natural advantages, resources, and geographical conditions confer market competitiveness to its agricultural products. To foster the sustainable development of agricultural trade, the governments of China and Mongolia are encouraged to establish favorable conditions by entering into pertinent trade agreements[9]. Furthermore, in the era of globalization, active participation in the international trade of agricultural products by China and Mongolia is essential to effectively expand the scale of agricultural trade and market share. Consequently, the continuous expansion and development of agricultural trade between China and Mongolia have emerged as a prominent aspect of economic and trade cooperation between the two nations.

5.2 Trade Structure Tends to Diversify

In the future, the trade structure of agricultural products between China and Mongolia will move forward and develop in the direction of diversification. On the one hand, Mongolia should pay attention to the reasonable adjustment of the agricultural industrial structure and strengthen the adjustment efforts. In recent years, with the change in market demand and economic restructuring of China and Mongolia, the trade structure has shown a diversified trend, which is not only reflected in the increase of agricultural products but also involves mechanical and electrical products and textiles and other aspects. Thus, the agricultural trade cooperation between China and Mongolia is more in-depth and extensive, adding much vitality to the economic development.

5.3 Trade Facilitation Level is Constantly Improving

To ensure that the agricultural trade between China and Mongolia achieves in-depth development, the government should pay attention to the implementation of specific measures to effectively improve the level of trade facilitation of agricultural products. For example, the construction and opening of the "green channel" in Erlian Port has effectively shortened the customs clearance time and reduced the cost of customs clearance. At the same time, the government departments of China and Mongolia have also signed bilateral trade agreements to provide many facilities for the trade of agricultural products and create a good and efficient environment[10]. In this way, it not only improves the efficiency of the actual circulation of agricultural products but also realizes the competitive strength of agricultural products of China and Mongolia in the market.

5.4 Agricultural Cooperation and Mutual Benefit and Win-Win Situation

Cooperation between China and Mongolia in agriculture shows a trend of mutual benefit and a win-win situation. China is a traditional agricultural country with rich agricultural resources and advanced agricultural technology, while Mongolia has suitable climatic conditions and vast land resources. Cooperation between the two countries in the agricultural industry can not only improve the efficiency of agricultural production but also achieve the continuous expansion of the export market of agricultural products. In the future, the agricultural trade cooperation between China and Mongolia will be deepened continuously, and through mutual benefit and win-win way, the competitive strength of agricultural products will be improved, which will bring a lot of power and vitality to the economic development of the two countries.

6 CONCLUSION

To sum up, when China and Mongolia cooperate in the field of agricultural products, they not only bear the responsibility of promoting economic development but also enhance the friendship between the people of China and Mongolia and promote common prosperity. With the advent of globalization and the trend of regional economic integration, agricultural trade between China and Mongolia has entered an important period full of challenges and opportunities. However, at this stage, there are many problems in the trade of agricultural products between China and Mongolia, which are mainly reflected in the single trade structure, quality and safety issues, high logistics and transport costs, trade barriers and friction, etc. Specific countermeasures should be put forward to optimize the trade structure, strengthen quality supervision, reduce logistics and transport costs, and strengthen the communication and coordination of policies. Through the implementation of these countermeasures, we can improve the level of agricultural trade between China and Mongolia, and promote the healthy and sustainable development of agricultural trade between China and Mongolia. Looking ahead, through the joint efforts of China and Mongolia as well as exploration, agricultural trade is facing a very broad prospect of development. As the scale of trade between China and Mongolia continues to expand, we can give full play to the advantages of resources, and effectively improve the quality of agricultural products through the optimization of the trade structure, so that the needs of the consumer groups in China and Mongolia can be fully satisfied.

COMPETING INTERESTS

The authors have no relevant financial or non-financial interests to disclose.

REFERENCES

[1] Liu Tiejian,Ding Xiaocui. Standards - Helping Green Development and Promoting Smooth Trade - The Second Sino-Mongolian International Standardisation Forum Held in Hohhot. Popular Standardisation, 2023, (17): 1.
[2] Qiao Ting, Zhao Haidong. Constructing a New Pattern of Beef and Lamb Trade between China and Mongolia and Technical Assistance to Livestock Husbandry in Mongolia. Scientific Management Research, 2022, 40(06): 164-172.
[3] Yang Ximing,Dong Sifei,Gao Zhigang. Research on Capacity Cooperation in China-Mongolia-Russia Economic Corridor--Dynamic Analysis Based on Trade Competitiveness of Segmented Industries. Price Monthly, 2022, (09): 52-64.
[4] Zhang Yuqing, Xiong Juan. Study on the New Development of Sino-Mongolian-Russian Transport Service Trade Cooperation. Foreign trade and economic cooperation, 2022, (03): 24-26+82.
[5] Zhang Jun, Lu Zechan. Assessment of trade effects of China-Mongolia free trade zone - Simulation analysis based on dynamic GTAP model. International Business Research, 2021, 42(06): 85-95.
[6] Gao Bin, Li Ping. Study on China-Mongolia Agricultural Trade under the Perspective of National Demand Level. Rural Economy and Science and Technology, 2021, 32(17): 111-113.
[7] Zhang Wenya, Li Ping. "Research on trade facilitation level of agricultural products in China-Mongolia-Russia economic corridor. Rural Economy and Science and Technology, 2021, 32(17): 117-119.
[8] Husletu, Jingjing. Reflections on the further development of Sino-Mongolian border trade. China market, 2021, (26): 16-17.
[9] Jiang Haiyan. Study on the Characteristics and Influencing Factors of Agricultural Products Trade between China and Mongolia under the Background of "Belt and Road". Journal of Inner Mongolia University of Finance and Economics, 2021, 19(03): 94-99.
[10] Shen Kaihong, Zhao Jinxin, Tian Zhihong. Analysis of Mongolia's foreign trade in agricultural products and China-Mongolia bilateral trade. World Agriculture, 2018, (04): 17-22+195.

Eurasia Journal of Science and Technology
ISSN: 2663-1016
DOI: 10.61784/ejst3009

TEACHERS' EDUCATIONAL LEADERSHIP EXERCISE UNDER MASLOW'S THEORY OF MOTIVATION

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Abstract: Maslow's theory of motivation posits that human needs can be structured hierarchically. This hierarchical structure consists of physiological needs, safety needs, social needs, esteem needs, and self-actualization needs, progressing in a specific order. Individuals will only pursue higher-level needs once their lower-level needs have been satisfied. This theory has been widely applied in the realm of social sciences, providing a systematic framework for understanding human behavior and motivation. Educational leadership of teachers refers to the influence and capabilities demonstrated by educators during the teaching process, enabling them to inspire students' learning potential and guide them towards common goals. This form of leadership is not only reflected in the selection of teaching methods and strategies within the classroom but also in the attention and support given to students' development. Through positive communication, motivation, and demonstration, teachers can shape students' academic achievements and personal character, laying the foundation for their future success. In this process, teachers are not merely conveyors of knowledge; they act as guides and inspirers, promoting educational advancement and societal development through their practice and influence. This paper primarily analyzes two theories, examining their defined dimensions in the context of educational studies, and drawing comparisons that lay the groundwork for future research.
Keywords: Theory of motivation; Educational theory; Teacher leadership

1 THE IMPACT OF MOTIVATION ON ORGANIZATIONAL BEHAVIOR

Motivation is not merely a product of psychological activity; it is a process of the evolution of internal psychological dynamics. The core of this process lies in goal setting, as goals are crucial for guiding individual behavior and providing the initial impetus. When individuals develop an awareness of a particular goal, external incentives gradually transform into internal needs, which then become a powerful force driving behavior. Furthermore, motivation not only necessitates individuals to engage in physiological activities but also drives psychological activities, which together form significant means for individuals to achieve their objectives.

Therefore, the impact of motivation on individuals is fundamental, as it profoundly reflects the essence of specific behaviors. Through these behaviors, we can gain insight into individuals' values and fundamental needs. From the perspective of organizational behavior, the study of motivation is crucial for understanding individuals' behavior patterns within teams or organizations, improving work efficiency, and promoting the achievement of organizational goals.

Contemporary motivational psychologists, from the perspective of cognitive psychology, propose that motivation is an intrinsic psychological process or internal drive that guides, inspires, and facilitates individual activity through goals or objects. In other words, motivation is guided and inspired by a certain goal and generates the driving force to push the individual's behavior [1]. However, where does this driving force originate? It stems from the individual's perception of the goal, i.e, when an external trigger is transformed into an internal need, this need becomes the driving force for the individual to engage in a certain activity[2], For example, for children who are about to enter school, school may initially be just an external inducement. However, under the guidance of adults or the influence of their peers, students gradually develop an understanding of school and then form expectations or needs for schooling. This need becomes the driving force for children to go to school and study, and going to school and studying becomes the specific goal of their behavior. This implies that motivation only arises when a target becomes an individual's necessity. Therefore, needs constitute the true driving force behind human behavior. It's worth noting that individual goals may initially be imperfect, and they may change correspondingly with shifts in the environment, personal cognition, and evolving needs.

Furthermore, motivation plays a crucial role in organizational operations. While employees' abilities and talents represent their potential value, these alone cannot be directly translated into tangible contributions to the organization. It is only when employees can fully leverage their abilities and talents that they can deliver substantial benefits to the organization. The extent to which employees can harness their capabilities and talents largely depends on their level of motivation [3].

Regardless of how advanced an organization's technology and sophisticated its hardware facilities are, these resources cannot be fully utilized and leveraged unless they are mastered and applied by employees who are highly motivated. Therefore, it can be said that the core of management lies in motivation. Inspiring the work motivation of each employee is one of the important missions entrusted to organizational managers. Through effective motivational

measures, managers can harness employees' enthusiasm and creativity, enabling them to wholeheartedly engage in their work and contribute as much as possible to the organization's development.

Motivation refers to the strong inner drive that compels individuals to engage in certain activities and commit to specific goals. The source of this drive lies in whether the goals can, and to what extent they can, satisfy personal needs. Motivation encompasses three core elements: first, it determines the direction of behavior, which serves as the basis for individuals' decision-making when choosing actions; second, it reflects the level of effort, indicating the degree of commitment an individual invests during the execution of a behavior; finally, it represents the level of persistence, showing how much effort an individual is willing to exert to maintain their choices and behaviors when faced with difficulties and challenges. Together, these three elements constitute a complete framework of motivation, influencing individuals' decision-making and behavioral performance.

Based on the above analysis, we can categorize motivation into different dimensions based on its distinct characteristics, as summarized in Table 1.

Table 1 Characteristics of Motivation and Corresponding Dimensional Distinctions

Motivational Characteristics	Dimension	Description
Goal Setting as the Core	Goal	A key factor that guides the direction of individual behavior and provides the original drive
Transformation of External Incentives into Internal Needs	Need	External incentives are transformed into internal needs, which become a strong driving force for behavior
Driving Physiological and Psychological Activities	Activity	Motivation not only drives physiological activities but also psychological activities, collectively forming important means to achieve goals
Reflecting the Essence of Individual Behavior	Behavioral Essence	Motivation profoundly reflects the essence of individual specific behaviors, revealing personal values and fundamental needs
Significance in Organizational Behavior	Organizational Behavior	The study of motivation is important for understanding individual behavior patterns within teams or organizations, enhancing efficiency, and promoting the achievement of organizational goals
Cognitive Psychology Perspective	Internal Psychological Process	Motivation is an internal psychological process or internal drive that guides, inspires, and sustains individual activities through goals or objects
Evolution of Goals and Needs	Evolution	Individuals' goals may be imperfect, and they can change as a result of the evolution of the environment, personal cognition, and needs

2 MASLOW'S THEORY OF MOTIVATION AND ITS SIGNIFICANCE FOR EDUCATION

Motivation, as an intrinsic driving force behind individual behavior, primarily arises from two core factors: needs and stimulation. Needs refer to the psychological states' individuals exhibit due to lacking something. This deficiency may originate internally, such as material elements required for physiological balance (e.g, water, food), or externally, such as psychological needs in social environments (e.g, social recognition, emotional connections) [4].

Maslow's theory of motivation provides us with a comprehensive framework for understanding human motivation. This theory not only reveals the hierarchical structure of human needs but also emphasizes the importance of fulfilling these needs for individual growth and development. In the field of education, Maslow's theory holds profound significance. It reminds educators to pay attention to students' basic needs, ensuring these needs are met to create an educational environment conducive to their holistic development. At the same time, educators need to recognize that different students may be at different levels of need hierarchy. Therefore, in educational practice, it is necessary to teach according to students' abilities and cater to their personalized needs.

Maslow categorizes human needs into two main types: basic needs and growth needs. Each type carries distinct characteristics and significance. Firstly, basic needs are closely tied to human instincts and exhibit five notable traits: Firstly, their absence can lead to health issues. Secondly, once satisfied, they can alleviate disease concerns. Thirdly, their restoration can aid in healing related ailments. Fourthly, when faced with complex and free choices, people tend to prioritize fulfilling these basic needs over others. Lastly, in healthy individuals, these needs often remain relatively stable, subdued, or latent. Basic needs primarily include physiological needs (such as food, water), safety needs, needs for love and belonging, and needs for respect [5].

The other type is growth needs, which are not directly governed by instincts and exhibit unique characteristics: on one hand, they are not directly influenced by human desires; on the other hand, they are driven by individuals striving to fulfill their potential; most importantly, satisfying these needs can bring deep, maximum happiness. Growth needs encompass the need for knowledge, aesthetic needs, and the need for self-actualization. By arranging these two types of needs in a hierarchy from lower to higher based on their direct importance to individual survival and meaningful living, the famous hierarchy of needs theory is formed. This theory not only reveals the complexity and diversity of human needs but also provides valuable insights for fields such as education and psychology.

Under the guidance of the hierarchy of needs theory, we understand that when various needs are unmet, individuals will first focus on satisfying the most urgent basic needs. This sequential order applies not only to the workplace but also has profound implications in the field of education. In an educational environment, meeting students' most fundamental physiological needs is the primary foundation.

Therefore, educators first need to create a learning environment that is both comfortable and safe for students. This means ensuring that students do not suffer from heatstroke in the summer and are not injured by cold temperatures in the winter. At the same time, learning facilities such as desks and chairs should be safe and complete. Only under these conditions can students focus on learning without worry, thus stimulating their enthusiasm and initiative in learning. When students' physiological and safety needs are met, they can concentrate more on learning and pursue higher learning quality. Such an environment also provides them with ample energy to explore and satisfy higher-level needs such as knowledge, aesthetics, and self-actualization. Therefore, meeting students' basic needs is the cornerstone of educational work and an essential prerequisite for promoting students' comprehensive development.

In the process of educating and managing students, we must pay special attention to and fulfill their needs for respect and self-fulfillment. As important guides in students' growth, teachers should fully respect students and actively guide them to discover and achieve their life values [6]. Among these needs—respect and self-fulfillment—respect is particularly crucial for students because it directly relates to their psychological well-being. Respect needs can further be categorized into internal and external respect. Internal respect refers to students' self-esteem, which manifests as their desire for confidence and the ability to independently handle various learning and life tasks. Therefore, when educating and managing students, teachers should adopt an encouraging approach to help them build confidence and establish lofty ideals [7] By affirming students' efforts and achievements, teachers can stimulate their intrinsic motivation, encouraging them to pursue self-fulfillment more actively. Additionally, teachers should create an environment filled with respect and love for students, enabling them to not only receive respect but also learn to respect others, thus achieving harmonious coexistence among people.

Maslow's "Hierarchy of Needs Theory" profoundly reveals the natural law of human needs evolving from lower to higher levels in a gradual and progressive manner. This theory not only aligns with the general laws of human physical and psychological development and the evolution of needs, but it also showcases its unique value and profound influence through continuous development and refinement. In 1954, Maslow supplemented the original five basic needs with two additional ones, which not only enriched the theoretical content but also made the pathways and goals for fulfilling needs more specific and clearer. This comprehensive theoretical framework provides valuable guidance in fields such as education and management, helping us to better understand human needs and thereby more effectively promote individual holistic development and the long-term progress of organizations.

Maslow's Hierarchy of Needs Theory profoundly reveals that at different stages, an individual's need system is characterized by one dominant need, while other needs are relatively subordinate. This perspective aligns closely with the materialist dialectics we have long adhered to, further affirming the importance of primary and secondary contradictions at a philosophical level. Through this theory, we gain a clearer understanding of the necessity to accurately grasp and meet an individual's dominant needs in management work, while also appropriately addressing other subordinate needs to achieve optimal management outcomes. This theory not only provides practical guidance for management practices but also offers a solid philosophical foundation.

The Hierarchy of Needs Theory is rooted in the core idea that "human motivation arises from human needs," which resonates with the fundamental principles of psychology and provides a solid psychological foundation for both the theory itself and its application in management practices. Psychology widely acknowledges that human behavior is driven by motivation, which, in turn, originates from various individual needs. It is these diverse needs that form the unique motivational systems of individuals. Maslow also emphasizes that human needs are the source of motivation. He illustrates this point with vivid examples: for instance, the fulfillment of physiological needs (such as food and water) drives people to work hard to ensure basic survival conditions, while the fulfillment of esteem needs motivates individuals to adhere to moral laws to earn respect and recognition from others. These examples clearly demonstrate the close relationship between needs and motivation, as well as the practical value of the Hierarchy of Needs Theory in management practices.

3 TEACHER'S LEADERSHIP

3.1 Case Analysis and Interpretation

Zhang Guimei, female, Manchu ethnicity, born in June 1957, Communist Party member, serves as the Party branch secretary and principal of the Huaping Women's Senior High School in Lijiang, Yunnan Province. She is also the director of the Huaping County Children's Welfare Institute. Zhang has been honored with various accolades including "Role Model of the Times," "National Advanced Worker," "National Model of Teacher Ethics," "Most Beautiful Rural Teacher in China," "Model for Poverty Alleviation Campaign," and "Touching China 2020 Person of the Year." [8]

Zhang Guimei is dedicated to her work and treats her students like her own children. In order to prevent a girl from dropping out of school due to poverty, she persisted in home visits for 11 years, visiting more than 1300 impoverished households and traveling over 100,000 kilometers. [9], her extraordinary efforts have strained her already frail body, but they have also resulted in excellent academic achievements for the female high school students. She spared no effort to fulfill her promise to "stand on the platform as long as I have breath," paving the way for impoverished students to

change their destinies through knowledge with practical actions. Over the years, she has lived in the student dormitories, eating and living with the children, accompanying them in their studies and daily lives. Zhang Guimei has educated and led her students with her unwavering dedication over decades.

The research on teacher leadership in the West emerged in the 1980s. American scholars Silva and others integrated the research on defining the connotation of teacher leadership over the past two decades and divided it into three phases according to the different perspectives of definition. [10]:

In the first stage, teacher leadership was assumed through roles such as research group leader, homeroom teacher, and union representative. In the second stage, researchers began to focus on the importance of teacher participation in curriculum leadership, emphasizing the leadership roles teachers play in team management, curriculum development, and professional development. In the third stage, the spirit of participation and collaboration among teachers is seen as central to reshaping the organizational culture of schools. Researchers place greater emphasis on the self-directedness and collaborative participation of teachers in defining teacher leadership. Undoubtedly, in the case of Zhang Guimei, her practical work demonstrates her high level of teaching professionalism and teacher leadership.

In recent years, researchers have proposed a fourth stage of teacher leadership. As research has progressed, the focus has shifted towards teachers' autonomous leadership in classroom teaching [11], identifying this as a key trait of teacher leadership. For the last few years, scholars from countries such as the United States, Canada, Australia, and New Zealand have questioned the authoritarian leadership styles prevalent in schools, making teacher leadership a hot topic in international research.

"A sheep leading a pack of lions cannot match a lion leading a flock of sheep." American leadership expert John C. Maxwell believes that leadership is synonymous with influence. According to American scholars Chapman and O'Neil, leadership is the ability of one person to influence others, especially to inspire them to achieve challenging goals. From this perspective, teachers' leadership manifests in their influence over students, colleagues, and friends, particularly in how they motivate students to reach academic goals and even pursue life aspirations. This leadership extends beyond classroom interactions to encompass communication with colleagues, school administrators, and parents. Teachers' leadership is comprehensive, covering every significant aspect of the educational process.

3.2 Characteristics of Teacher Leadership

Early scholars primarily focused on transformational leadership in macro fields such as politics, business, and military affairs [12]. In these domains, transformational leadership has shown significant efficacy compared to other leadership styles, notably stimulating subordinates' enthusiasm and creativity, thereby achieving results far beyond expectations. This notable success swiftly drew widespread attention from experts in the field of education. They conceptualized classrooms or lessons as miniature communities or teams, where teachers, as conveyors of knowledge and guides to student development, naturally emerged as pivotal leaders within these small-scale communities. Against this backdrop, educational scholars began exploring the potential of integrating transformational leadership into classroom teaching. The aim is to foster teachers' professional development through this innovative leadership approach, positively and profoundly impacting student achievement and holistic development.

During the same period, research on transformational leadership was flourishing on American university campuses. In 2008, prominent American educational scholar Pounder conducted extensive studies revealing the significant impact of transformational leadership in teaching practices. Specifically, teachers experienced marked improvements in their satisfaction with their teaching effectiveness. Concurrently, there was a notable increase in students' satisfaction with their teachers. Most notably, classroom participation among students was greatly enhanced, with students becoming more actively engaged in learning activities, demonstrating heightened enthusiasm and initiative for learning.

In 2010, experts in the field of education in the United States, Bolkan and Goodboy, developed a tool called the Multifactor Leadership Questionnaire (MLQ) based on a synthesis of prior research. This tool systematically explored students' perceptions of teachers' transformational leadership in the classroom from both quantitative and qualitative dimensions, as well as the potential relationship between such leadership and student achievement.

Transformational leadership theory posits that idealized influence measures followers' admiration and respect for a leader, often through strong personal charisma that inspires subordinates. In modern classrooms, students increasingly favor teachers who possess strong personal charisma. Leveraging vibrant classroom content and fluent communication skills, teachers vividly impart knowledge. Their humorous and engaging teaching styles break the monotony of traditional classrooms, making learning lively and enjoyable, thereby encouraging students to transition from passive recipients to active seekers of knowledge. During instruction, teachers adeptly cultivate a democratic, friendly, equitable, and harmonious learning environment where every student feels the warmth and vitality of the classroom. In such settings, teachers not only assume the role of transformational leaders but also act as facilitators and participants in classroom dynamics. They skillfully utilize and integrate various factors within the classroom, creating a cohesive and harmonious whole. Through these teaching activities, students' initiative in learning is fully ignited, as they actively engage in a productive and harmonious classroom atmosphere.

However, intellectually stimulating leaders excel in igniting subordinate creativity. They focus on nurturing novel ideas and concepts while encouraging subordinates to seek innovative solutions from multiple dimensions and perspectives. Teachers equipped with the ability to intellectually stimulate demonstrate flexible and adaptable teaching strategies in the classroom. They are particularly skilled at utilizing multimedia resources, such as slides and videos, to enhance instruction, significantly boosting students' enthusiasm for thinking. Teachers with a transformational leadership style

can effectively mobilize students' intrinsic motivation for autonomous learning during teaching practices, making the classroom experience more efficient and orderly, thereby improving the quality of instruction. Students generally believe that when teachers adopt diverse teaching methods to create problem-based contexts, it effectively stimulates their learning motivation. Furthermore, the intuitive presentation of multimedia teaching aids helps them better understand and grasp the key points and challenges of the material.

The transformational leadership theory emphasizes that inspirational motivation is key for leaders to instill vision and a sense of mission among their subordinates, aiming to cultivate pride and a positive, optimistic attitude. Similarly, teachers who possess transformational leadership traits exhibit similar wisdom in education. They grant students significant freedom and space, returning the autonomy of learning back to them, deeply trusting in their innate potential and abilities. These transformational teachers place particular emphasis on creating an environment where students can explore, apply, interact, and self-assess. They encourage students to expand their boundaries of knowledge through activities such as practical exercises, observation, questioning, and discussion, nurturing their innovative thinking and creativity. Throughout this process, teachers provide ample time for exploration, allowing students to grow in a free academic atmosphere. This approach effectively stimulates students' creative potential and cultivates them into future innovators.

Personalized care is a key element of transformational leadership theory, which requires leaders to possess excellent listening skills, keen observational abilities, and profound patience and perseverance. When faced with the diverse needs and situations of their subordinates, leaders must flexibly adjust their work plans to ensure optimal outcomes. This theory is equally applicable in the field of education. Transformational teachers must first possess the ability to tailor their teaching methods to the individual needs of their students. They should gain a deep understanding of each student's circumstances and adopt a flexible and varied approach to education that is targeted and purposeful. Through personalized guidance and support, teachers can help students fully realize their potential and achieve holistic development. Additionally, transformational teachers should be adept at employing motivating feedback language. They should actively encourage students, help them build self-confidence, and enable them to experience the joy of success. This positive feedback not only stimulates students' enthusiasm for learning but also empowers them with uplifting energy as they feel the care and love from their teachers. Through personalized care and motivational feedback, transformational teachers can create a nurturing environment filled with love and hope for their students' growth.

Based on the above analysis, the characteristics of teacher leadership can be categorized into corresponding dimensions for a better conceptual summary, as shown in Table 2.

Table 2 Characteristics of Teacher Leadership and Corresponding Dimensional Differentiation

Characteristics of Teacher Leadership	Dimension	Description
Idealized Influence	Personal Charisma	Demonstrates strong personal charisma through rich classroom content, fluent language expression, and humorous communication, earning admiration and respect from students
Intellectual Stimulation	Cultivation of Creative Thinking	Trains students in creative thinking, fostering new concepts and ideas, encouraging multi-perspective problem-solving, and utilizing various teaching methods
Inspirational Motivation	Vision and Mission	Instills vision and a sense of mission in students, cultivating pride and a positive optimistic attitude, granting students freedom and space, trusting their inherent potential and abilities
Personalized Care	Tailoring Teaching to Individual Needs	Deeply understands each student's circumstances, employs flexible and diverse teaching methods, provides targeted education, uses motivational feedback language, and helps students build confidence

4 CONCLUSION

Based on the analysis of Maslow's hierarchy of needs theory and educational leadership in the teaching context, it is evident that both theories share a common fundamental goal: to understand and facilitate human development towards higher objectives. Maslow's theory emphasizes the importance of fulfilling basic needs before progressing towards higher goals, which aligns with the role of educators in nurturing students' fundamental skills and personal growth. Educational leaders, represented by teachers, not only impart knowledge but also cultivate motivation and character, thereby shaping students' academic achievements and social contributions. By integrating these theories, educators can improve teaching strategies, better support student progress, create a more enriching learning environment, and establish and achieve higher learning goals.

COMPETING INTERESTS

The authors have no relevant financial or non-financial interests to disclose.

REFERENCE

[1] Li R, Cui Y, Zhang C, Han Q. The relationship between college students' cognitive demands and critical thinking: The mediating role of work motivation. Abstracts of the 21st National Psychology Academic Conference, 2018.
[2] Ma Y, Li T, Liu X. Tourist behavior. Science Press, 2008.
[3] Zhan W. Application of motivation theory in power enterprise management. Human Resources Development, 2012, (12), 2.
[4] Hu F. Sustainable Profit DNA Economic Theory, Regulations. China Fortune Publishing House, 2016.
[5] Liu C. Analyzing the dilemmas and solutions of young university teachers based on Maslow's needs theory. University: Social Science, 2020.
[6] Bao X. The influence of teachers on students' learning interest in mathematics classrooms. Basic Education Research, 2015, (16), 1.
[7] Zhao S. The influence of Maslow's hierarchy of needs theory on educational management. Exam Weekly, 2018, (89), 1.
[8] Li Y, Pang M, Zhang G. "Principal Mom" of the mountain girls—A profile of Zhang Guimei, principal of Yunnan Lijiang Huaping Women's Senior High School. Global Business Classics, 2021, (3), 6.
[9] Xu H. Zhang Guimei: A role model educator. Yunnan Education: Vision, 2022, (18), 4-5.
[10] Quan S, Yin Z. Exploration of teaching reflection and teacher development. Guangming Daily Publishing House, 2016
[11] Luo T. A brief discussion on leadership of university teachers. New Curriculum (Part II), 2015, (3).
[12] Tang W, Zhao J. A discussion on the influence of teacher transformative leadership on students. Times Literature: Second Half Month, 2015, (7).

Eurasia Journal of Science and Technology
ISSN: 2663-1016
DOI: 10.61784/ejst3010

APPLICATION PROSPECT AND RISK ANALYSIS OF GENERATIVE ARTIFICIAL INTELLIGENCE TECHNOLOGY IN HIGHER EDUCATION

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Abstract: Nowadays, generative artificial intelligence technology is closely related to many subdivisions in higher education, and its impact on higher education is increasingly apparent. This paper discusses the potential and risk of the application of generative artificial intelligence technology in higher education. In terms of application potential, it can be divided into five aspects: innovation of learning mode, effective promotion of knowledge production, extension of evaluation system dimension, wisdom innovation of teaching mode, and stimulation of educational concept transformation. In terms of application risk, it is mainly divided into five aspects: the doubt of knowledge legitimacy and authenticity, the risk of data security and privacy, the impact on students' discerning and creative thinking, the ban on users' imagination and innovation, and the ethical and moral risks associated with information output. The application of generative artificial intelligence technology in the field of education involves a multi-faceted and multi-level process. It is necessary to clarify the advantages and disadvantages of generative artificial intelligence technology in order to better play the potential of generative artificial intelligence application in the field of education and promote the digital transformation and upgrading of education.
Keywords: Generative artificial intelligence; Higher education; Application potential; Application risk

1 INTRODUCTION

In 2023, China issued the Interim Measures for the Management of Generative Artificial Intelligence Services, which pointed out that the bottom line should be drawn, refined supervision should be carried out, artificial intelligence should be promoted to be better, and effective measures should be taken to encourage the innovative development of generative artificial intelligence. This marks that China's artificial intelligence services have entered a new stage, further clarify the red line of the system, say goodbye to the situation of unclear system in the past, for the field of colleges and universities, it is necessary to actively grasp the development opportunity, combine artificial intelligence with scientific research and teaching, and cross multiple fields for teaching and scientific research innovation. In 2021, the Ministry of Education and the Ministry of Finance issued the Notice on the Implementation of the National Training Plan for Primary and Secondary School Kindergarten Teachers (2021-2025), pointing out that to promote the integration of artificial intelligence and teacher training, explore "intelligence + teacher training", and form a mechanism for artificial intelligence to support teachers' lifelong learning and sustainable development. At the end of the plan, the field of colleges and universities should refer to the content of the plan, combine the development needs, grasp the new momentum of science and technology, use generative artificial intelligence to empower, build a high-quality teacher team, and promote the high-quality development of college education. In 2019, the General Office of the CPC Central Committee and The General Office of the State Council issued Several Opinions on Deepening the Reform and Innovation of Ideological and Political Theory Courses in Schools in the New Era, proposing to "vigorously promote the reform of teaching methods of Ideological and political courses, and promote the application of modern information technologies such as artificial intelligence in the teaching of ideological and political courses"[1]. As a place for ideological and political communication, colleges and universities should actively play a leading role in ideological and political communication, actively use new technologies and new methods to build an AI+ teaching model and build high-quality ideological and political classrooms.

The vigorous development of artificial intelligence has given birth to large generative AI models such as chatGPT and Wenxin Yiyi. By December 2023, chatGPT had 180 million users, generating 1.7 billion web page views per month, and Wenxinyiyi had 100 million users. According to the statistics of Baidu Search Index on March 20, 2024, the average daily searches were 30, 600 and 141, 900 respectively in the past 30 years. Among them, users aged 20-39 account for more than 70% of the search volume, with a male/female ratio of about 6:4. The highest daily search index values in China are 3.5 million and 9.52 million, respectively; The data show that more and more users choose to use generative artificial intelligence. According to the Basic Situation of National Education Development in 2023 released by the Ministry of Higher Education, there are 2.074, 900 full-time teachers in higher education in China, and 47, 631, 900 students in various forms of higher education[2]; According to incomplete survey statistics, 75.56% of teachers in colleges and universities have the idea of using generative artificial intelligence, and 52.89% of teachers are already using generative artificial intelligence. College teachers shoulder the responsibility of teaching students knowledge, cultivating students' skills, academic research and innovation in the field. Generative AI empowers the teaching and research of university teachers to assist in teaching, provide personalized learning services, innovate

teaching methods and acquire knowledge base to support the teaching and research of teachers. Therefore, the empowering potential and application risks of generative AI in the field of education will become the focus of research in the field of education.

2 HISTORY OF GENERATIVE ARTIFICIAL INTELLIGENCE

The term "artificial intelligence" originated in the mid-20th century when it was proposed by John McCarthy and the development of artificial intelligence was jointly promoted by many researchers[3]. Artificial intelligence is a broad concept that covers a variety of techniques and methods for mimicking human intelligent behavior; It aims to solve a wide variety of problems, ranging from simple rule-based systems to complex deep learning models. With the rapid development of science and technology, the world has entered a new era of artificial intelligence. The generative artificial intelligence technology represented by ChatGPT and the application of large language model are leading a new round of information technology reform and promoting the rapid development of the industry. Different from traditional artificial intelligence systems, generative artificial intelligence technology can generate new data according to given input, including text generation, image generation, video generation, audio generation, etc.[4]. Due to its cross-border and efficient integration advantages, generative artificial intelligence technology has quickly become a facilitator, designer and operator of human practice in all fields and all-factor integration, and an "operating system" of a deeply media society[5]. The development of generative AI technology has brought new ideas and methods to the field of artificial intelligence, and promoted the continuous innovation and progress of artificial intelligence technology.

Artificial intelligence and generative artificial intelligence play an important role in the field of artificial intelligence. Artificial intelligence is a broad concept. It covers a variety of techniques and methods for mimicking human intelligent behavior. It aims to solve a variety of problems, ranging from simple rule-based systems to complex deep learning models. Generative artificial intelligence is a specific type of artificial intelligence. It focuses on using models to generate new data. Although they differ in terms of definition, function and application, the two are intertwined and closely related in terms of technical foundation and mutual enhancement.

With the rapid development of science and technology, the world has entered a new era of artificial intelligence, and the application of generative artificial intelligence and large language model represented by ChatGPT is leading a new round of information technology reform and promoting the rapid development of the industry[6]. Different from traditional AI systems, generative AI can generate new data according to given input, including text generation, image generation, video generation, audio generation, etc. Due to its cross-border and efficient integration advantages, generative artificial Intelligence has quickly become a facilitator, designer and operator of human practice in all fields and all-factor integration, and an "operating system" for a deeply media society[5]. The development of generative artificial intelligence has brought new ideas and methods to the field of artificial intelligence, and promoted the continuous innovation and progress of artificial intelligence technology. As an unprecedented "super medium", generative artificial intelligence has shown great potential.

3 RESEARCH ON THE APPLICATION POTENTIAL OF GENERATIVE ARTIFICIAL INTELLIGENCE IN THE FIELD OF EDUCATION

Generative AI empowers education and adds "intelligent wings" to education. By virtue of its highly intelligent interaction, creative generation, complex data processing and other capabilities, it improves traditional and inefficient scientific research and teaching methods, promotes the change of learning methods in the field of education[7], promotes the innovation of knowledge production and learning methods, and reshapes teaching activities[8] and expand a new dimension for evaluation in the field of education[9].

3.1 Generative Artificial Intelligence Effectively Promotes Knowledge Production

The data scale and algorithmic advantages of generative AI make it gradually become the core force of knowledge production. First, it accelerates the comprehensive data of knowledge production and the full scene of knowledge connection[10]; second, it has the characteristics of high knowledge density, fast generation speed and low generation cost[11]. It makes man-machine collaboration in the knowledge production process become closer, knowledge opening and sharing become more common and easy, and the production mode changes from individual knowledge emergence to generative knowledge emergence[12]. Its powerful knowledge generation ability, knowledge creation, sorting and dissemination become more efficient and intelligent, this change of knowledge logic and generative logic effectively promotes knowledge exchange and integrated development, and creates opportunities for cultivating a higher level of collective intelligence.

3.2 Generative Artificial Intelligence Promotes the Innovation of Learning Methods

Generative AI provides efficient and personalized intelligent services and technical support for learning objects. First, generative artificial intelligence is the integration of large model technology, knowledge base technology and all kinds of intelligent education technology. It takes learners as the center and has the interactive question-and-answer function based on the huge knowledge base, showing obvious advantages in learning forms, role playing and interaction process[13]. It can play the role of tutor, assistant, companion and evaluator for learners, and has significant advantages

in supporting learners' adaptive learning; Second, generative artificial intelligence can effectively make up for the lack of learning resources, strengthen academic guidance, accelerate learners' acquisition of innovative knowledge, break discipline barriers, guide research problem mining, and stimulate innovative thinking[14]. The unique advantages of generative artificial intelligence can help accurately analyze learners' preferences, recommend diversified learning materials, and generate recommendations by constructing prompts, generating recommendations and evaluation results, so as to better implement individualized teaching and reduce learners' burden.

3.3 Generative Artificial Intelligence Stimulates the Transformation of Educational Concepts

Generative AI empowers and educates people, and promotes the concept of education to shift to higher-order ability cultivation. First, the deep integration of generative artificial intelligence and education has a significant impact on education. The education model has changed from binary to triadic, from teacher-student interaction to teacher-student-AI interaction[15], from the use of machine learning to optimize education, to the use of deep learning to empower education, and to the use of general large model to innovate education, which is becoming more and more important; Second, artificial intelligence is changing education at an unprecedented speed, putting forward new requirements for the existence value, role positioning and professional quality of teachers[16]. Teachers need to continuously improve, in the knowledge transformation, man-machine collaboration, in-depth exploration of learning concepts, and provide support in the cultivation of students' abilities. Give full play to its significant advantages in the three aspects of education quality, education efficiency and education equity[17]. At the same time, it is necessary to focus on cultivating students' higher-order thinking ability, so that students can distinguish complex situations in reality and make clear that they are limited to instrumental attributes, so as to better tap their own potential for innovation and development.

3.4 Generative Artificial Intelligence Intelligently Innovates Teaching Methods

Generative artificial intelligence integrates into the classroom and explores innovative practical teaching. First, the emergence of generative artificial intelligence has brought a new pattern of education, marking a breakthrough in the relationship between artificial intelligence and education, and triggering the resonance of teaching and learning activities[18]. At this stage, the continuous iteration and upgrading of generative artificial intelligence has shown the basic ability of efficient accumulation of knowledge and rational use of knowledge. It can play the role of an assistant of teachers' educational resources, an assistant of students' self-study, an assistant of enhancing classroom learning interaction, and an assistant of automatic correction of extracurricular homework in teaching[19]; It can be seen that the generative teaching enabled by artificial intelligence turns data intelligence into teaching wisdom. Second, through the role transformation and relationship reconstruction among teachers, students and technology, and the combination of innovation and practice, artificial intelligence is regarded as a strategic technology leading the future development of society, and the development of the classroom towards intelligence is promoted[20]; The experiment found that the man-machine collaborative deep inquiry learning model and its teaching mode can significantly change students' learning performance[21], improve problem solving ability, enhance critical thinking ability, learning attitude and intrinsic learning motivation; Therefore, it is necessary to give full play to the principal role of students in education and help students build their own knowledge system. To truly empower students with wisdom and realize their all-round development[22].

3.5 Generative Artificial Intelligence Extends the Evaluation System Dimension

With its revolutionary technological innovation, artificial intelligence has exerted many influences on the current reform of college education evaluation. It brings new opportunities for the development of education and causes changes in educational goals, contents, forms and evaluation[23]. It makes the evaluation content multi-dimensional, the evaluation subject diversified and the evaluation technology diversified. In terms of scientific research, generative artificial intelligence improves the traditional and inefficient scientific research methods, and promotes the academic evaluation of universities to broaden the evaluation dimension[24]; In terms of traditional educational tools, based on man-machine collaboration, new educational forms and educational evaluation systems have been spawned[25]; In terms of student management, generative artificial intelligence technology can effectively use students' academic data to realize the automatic generation of reviews, providing decision-making support for assisting teachers to carry out personalized reviews[26]; In terms of integration and innovation of teaching content, for different professional student groups, generative artificial intelligence is used to generate simulated employment application scenarios, strengthen students' skill training, and promote the application and integration of college teaching[27].

4 RESEARCH ON THE APPLICATION RISK OF GENERATIVE ARTIFICIAL INTELLIGENCE IN EDUCATION FIELD

As a subversive technology, generative artificial intelligence still faces doubts about the authenticity and legitimacy of knowledge generation, data security and privacy risks generated by interaction, ethical and moral risks associated with information output, and bans on users' imagination and innovation, as well as affecting students' discerning and creative thinking.

4.1 The Authenticity and Legality of Knowledge Generation Remain in Doubt

First, generative artificial intelligence is based on large models and trained by large-scale data sets, which is essentially information reconstruction of real world content[28]. Its performance depends on the scale and quality of the training data set[29]; However, the one-sidedness of the training database may lead to unfair, incorrect, false information and other situations[30], which brings the risk of uncertainty to the user group. This kind of wrong information may be generated and disseminated, making it difficult for educators to distinguish. Second, the copyright of generative artificial intelligence-generated content has not been determined, the ownership configuration of human-computer interaction works is not clear, the boundary of reasonable use of intelligent generated content is fuzzy and the potential infringement risk of intelligent generated content utilization[31]. The specific performance is that the content uploaded by user groups is used to further train the model, while the generated content is difficult to distinguish from traditional works[32], and new problems in the field of intellectual property and criminal law have gone beyond the scope of regulation of the current law[33], and have challenged the existing legal framework.

4.2 Data Security and Privacy Risks Arising from Interaction

First, in the training process, generative artificial intelligence is based on knowledge data as the underlying logic, transforming the knowledge production relationship, promoting the multi-modal fission and aggregation of knowledge, and realizing the comprehensive data of knowledge production[34]. However, in the training process, the model may indirectly "remember" the sensitive information in some training data, such as trade secrets, patent information, etc., which may be accidentally leaked in the process of knowledge generation by the model. Second, when using generative AI, external data input is usually required to answer in combination with the framework of the existing knowledge system, and the communication process will be recorded and collected without consent, which will aggravate the risk of disclosure of private data such as raw numbers and generated data[35].

4.3 Information Output is Accompanied by Ethical and Moral Risks

First, the ethical risks of generative artificial intelligence in frontier science and technology have increasingly attracted high concern from the international community, and the ethical governance of science and technology in China is on the road of institutionalized development. As a machine, generative artificial intelligence only has instrumental significance, but does not have independent personality, and it is difficult to obtain the status of ethical subject[36]. At the same time, the irrational use of generative artificial intelligence will weaken the value of human subjects[37]. Although it promotes technological innovation, it also brings many social ethical risks. For example, the generation of fake news and comments will mislead the public, training data contains biases, and AI-generated content may also reflect these biases, thus exacerbating social discrimination, such as gender, race or age discrimination. Second, the "deep forgery" technology using generative artificial intelligence has a high possibility of falsifying information production and is widely used in pornography and telecom fraud[38]. The unreasonable use of artificial intelligence makes the number of false information increase, the generation speed is fast, the types are diverse and the virus is viral, and the content creation process and the implementation of false information activities are automated. As these features continue to improve and prolifze, they undermine trust in verifiable facts, further threaten democratic governance, and lead citizens to doubt the possibility of truth in public life[39].

4.4 The Containment of Users' Imagination and Creativity

First, generative artificial intelligence has diversified application scenarios in different disciplines. In the field of education, it can assist teachers in scientific research and teaching and student paper collaboration, in the medical field, it can assist clinical decision-making, and in the computer field, it can improve programming efficiency, etc.[40]. To some extent, it outsources users' demands to the outside world. Users are required to have sufficient knowledge reserves, transaction analysis and other key capabilities, otherwise users will easily fall into the education trap, leading to lazy thinking and cognitive fragmentation, and thus limiting the development of individual innovation[41]. Second, generative artificial intelligence (Sora) can generate detailed realistic and imaginative dynamic scenes composed of multiple characters, specific sports types, themes and backgrounds according to user instructions, constantly iterating and upgrading. Sora will become the knowledge overlord, surpass human beings in imagination and creativity, and thus realize the exclusion of human thinking. In the cultivation of human ability to realize the possibility of education alternative. Sora's instrumental rationality, false pretence, value deviation and other problems will dissolve the educative nature of education. In addition, the human-machine interactive learning model with visual, integrated and adaptive learning shaped by Sora will shake the foundation of the existence of the school as an entity[42].

4.5 It will Affect Students' Discerning Thinking and Creative Thinking

First, students' improper use of generative artificial intelligence is increasing. In view of the phenomenon that a large number of students use generative AI to generate homework, the experiment found that the experimental group's academic performance, critical thinking ability, problem solving ability and learning attitude were significantly better than the control group, but the effect of innovation ability was not significant. This result will affect the cultivation of

students' critical thinking and creative thinking. Second, at the present stage, artificial intelligence does not show the potential of enabling students to improve their autonomy by producing integrated content output after students ask questions[43]. Meanwhile, human-computer interaction will cause students to lack interpersonal communication, and students may be limited in understanding ability. Due to the limited personalized teaching ability of generative artificial intelligence, students may lose their ability of independent discernment and creative thinking.

5 CONCLUSIONS AND SUGGESTIONS

Generative artificial intelligence technology has shown a broad application prospect in the field of higher education, but it also comes with a series of challenges and risks. By analyzing the potential of generative AI technology in learning mode innovation, knowledge production, evaluation system expansion, teaching mode innovation and educational concept transformation, we can see that it has great advantages in improving education quality, optimizing teaching resource allocation, and promoting students' personalized learning. However, we can not ignore the risks in the authenticity and legitimacy of knowledge generation, data security and privacy protection, ethical and moral risks, potential restrictions on user creativity and imagination, as well as the impact on students' critical thinking and creative thinking.

In order to better realize the potential of generative AI technology in higher education and promote the digital transformation and upgrading of education, we need to take a series of measures:

(1) Strengthen and improve the construction of laws and regulations: formulate relevant regulations and ethical guidelines to clarify the boundaries of the use of generative AI in the field of education, protect intellectual property rights, ensure data security and privacy protection, and prevent possible ethical and moral risks.

(2) Improve teachers' and students' digital literacy: Through training and education, improve teachers' and students' understanding and application ability of generative AI technology, and enhance their discernment ability and critical thinking when using AI tools.

(3) Promote the deep integration of technology and education: In teaching practice, actively explore the integration of generative AI and traditional teaching methods, innovate teaching models, and promote education equity and teaching quality improvement.

(4) Strengthen cross-field cooperation: promote cooperation in education, technology, law and other fields, jointly study and solve various problems in the application of generative AI in the field of education, and promote the synchronous progress of technological progress and educational development.

(5) Carry out continuous risk assessment and management: establish a sound risk assessment mechanism, continuously monitor the application effects and potential problems of generative artificial intelligence in the field of education, and timely adjust and optimize relevant policies and measures.

COMPETING INTERESTS

The authors have no relevant financial or non-financial interests to disclose.

FUNDING

The research was supported by List of approved projects of China Private Education Association in 2024 (school development) on project of Research on the willingness and behavioral decision-making mechanism of private university teachers to adopt generative artificial intelligence technology (CANFZG24355).

REFERENCES

[1] Wang Tianming, Cong Xiaoli. Research on Artificial intelligence assisting tourism development in Hainan. Guide of Economic Research, 2019, (08): 108-110.

[2] Ye Ni, Yu Guoming. Innovative Content Production based on AIGC Extension: Scenarios, users and core elements. Social Science Front, 2023, (10): 58-65.

[3] Guo Yike. On the History, Present Situation and Future Development Strategy of Artificial Intelligence. People's Forum. Academic Frontiers, 2021, (23): 41-53.

[4] Wang Jing-jing, Ye Ying. Analysis on the transformation of information management and communication by generative AI and its GPT technology application. Journal of Library Science, 2023, 49(06): 41-50.

[5] Yu Guoming, Li Vanadium, Teng Wenqiang. AI+ Education: Upgrading and transformation of teaching model in the era of Artificial Intelligence. Ningxia Social Sciences, 2024, (02): 191-198.

[6] Fan Wei, Zeng Lei. Analysis on intelligent data generation Path for the activated utilization of cultural heritage in the new Era of AI. Journal of Libraries of China, 2024, 50(02): 4-29.

[7] Wan Ping, Gu Xiaoqing. Human-machine Collaborative Evaluation supported by Generative Artificial Intelligence: Practice model and Explanatory case. Modern Distance Education, 2024, (02): 33-41.

[8] Qin Yuchao, Liu Geping, Xu Ying. How Generative Artificial Intelligence reshapes Teaching activities: Model construction and application based on activity theory. China Distance Education, 2023, 43(12): 34-45.

[9] Xiao Jun, Reconstruction and Collaboration: Thinking of "Breaking Five Only" from the perspective of Generative Artificial Intelligence. Journal of Higher Education Administration, 2024, 18(02): 53-64.

[10] Cheng Sifan.ChatGPT Knowledge Production Framework, Technical myths and future evolution. Contemporary Communication, 2023, (06): 60-64.
[11] Liu Zhifeng, Wu Yaping, Wang Jimin. Influence of artificial Intelligence-generated content Technology on Knowledge Production and Dissemination. Journal of Information, 2023, 42(07): 123-130.
[12] Miganin, Dong Changqi. The era of Grand Model: the generative form of knowledge "emergence". Xuehai, 2024, (01): 81-96+214-215.
[13] Li Sen, Zheng LAN. Challenges and Responses of Generative Artificial Intelligence to Classroom Teaching. Curriculum. Teaching Materials. Teaching Methods, 2019, 44(01): 39-46.
[14] Zhou Wenhui, ZHAO Jinmin. The value and challenge of ChatGPT to the cultivation of graduate students' innovation ability. Journal of University Education Administration, 2019, 18(02): 42-52.
[15] Yang Zongkai, Wang Jun, Wu Di, et al. ChatGPT/ Generative Artificial Intelligence's impact on education and its countermeasures. Journal of East China Normal University (Educational Science Edition), 2023, 41(07): 26-35.
[16] He Qizong, Yan Zhiwei. The Aesthetic Quality of teachers in the era of Artificial Intelligence: Why it is necessary and Why it is generated. China Audio-Visual Education, 2021, (11): 46-53.
[17] Li Yanyan, Zheng Yafeng. Educational application of Generative Artificial Intelligence. People's Forum, 2023, (23): 69-72.
[18] Wu Gang, Yuan Lei. The Logic of Education and the Temptation of Artificial Intelligence. Educational Review of Peking University, 2023, 21(01): 2-26+187.
[19] Yang Xiaozhe, Wang Qingqing, Jiang Jialong. Analysis of teacher-student dialogue in classroom based on artificial intelligence: Automatic classification and level construction of IRE. Research on Audio-visual Education, 2023, 44(10): 79-86.
[20] Liu Bangqi. The Core value of classroom transformation enabled by artificial intelligence: wisdom generation and model innovation. Open Education Research, 2022, 8(04): 42-49.
[21] Zhai Xuesong, Chu Xiaoyan, Jiao Lizhen, et al. Research on Human-machine collaborative learning model based on "Generative Artificial intelligence + meta-universe". Open Education Research, 2023, 29(05):26-36.
[22] Zhou Ling, Wang Feng. Educational implications of generative artificial Intelligence: Let everyone be himself. China Audio-visual Education, 2023, (05): 9-14.
[23] Shang Zhichun, Yan Yuhong. The application of ChatGPT in education and its changes and ethical challenges. Journal of Northeast Normal University (Philosophy and Social Sciences Edition), 2023, (05): 44-54.
[24] Xiao Jun, Reconstruction and Collaboration: Thinking of "Breaking Five Only" from the perspective of Generative Artificial Intelligence. Journal of Higher Education Administration, 2024, 18(02): 53-64.
[25] Zhang Zhi. The Underlying logic and possible Path of ChatGPT/ Generative Artificial Intelligence Reshaping Education. Journal of East China Normal University (Educational Science Edition), 2023, 41(07): 131-142.
[26] Xiong Yu, Wang Ying, CAI Ting, et al. Modern Distance Education, 2023, (01): 32-39
[27] Wu Qinghua, Guo Lijun. Teaching Reform in Higher vocational colleges in the era of generative artificial Intelligence: Challenges, framework and path. University Education Science, 2023, (06): 112-120.
[28] Xu Lei. Integrated Regulation of content risk in Generative Artificial Intelligence. Publication and Distribution Research, 2024, (01): 59-66.
[29] Song Huajian. On the legal risk and governance path of Generative Artificial Intelligence. Journal of Beijing Institute of Technology (Social Sciences), 2024, 26(03): 134-143.
[30] 3. Fang Jiaojiao, Gao Tianshu. Hidden trouble of Generative Artificial Intelligence assisted administrative decision algorithm and its governance path. Huxiang Forum, 2024, 37(01):99-111.
[31] Zhao Feng. Challenges and responses to copyright system under Intelligent Generated Content Utilization: A case study of ChatGPT. Journal of Publication and Distribution Research, 2023, (03): 48-56+47.
[32] Chen Fengming. Challenges and Responses: Approach to copyright protection of Artificial Intelligence-Generated Content. Journal of Publication and Distribution Research, 2023, (06):20-28.
[33] Yuan Zeng. Legal Response to generative artificial Intelligence Governance. Journal of Shanghai University (Social Sciences Edition), 2024, 41(01): 28-39.
[34] Huang Kaijian, Yang Haiping. The Innovation of Knowledge Production in Intelligent Publishing under AIGC. Friends of the Editor, 2023, (12): 28-33.
[35] Liu Kang. Human mobile data generation methods: Research progress and trends. Journal of GeoInformation Science, 2024, 26(04): 831-847.
[36] Yang Guorong. Generative Artificial Intelligence (AIGC) and its philosophical Implications. Journal of Shanghai Normal University (Philosophy and Social Sciences Edition), 2024, 53(01): 110-115.
[37] Feng Zixuan. The Ethical Standpoint and Governance Approach of Generative Artificial Intelligence Application: A case study of ChatGPT. Journal of East China University of Political Science and Law, 2019, 27(01):61-71.
[38] Chen Ran. Criminal Law Regulation of deep Falsification of sexual information. Law Journal, 2024, (03): 76-90.
[39] Hu Yong. Artificial Intelligtion-driven false information: Present and future. Nanjing Social Sciences, 2024, (01): 96-109.
[40] Xia Qi, Cheng Miaoting, Xue Xiangzhong, et al. How to effectively incorporate ChatGPT into education from an international perspective: Based on a systematic review of 72 literatures. Modern Educational Technology, 2023, 33(06): 26-33.

[41] Yu Shengquan, Wang Fancong. Cognitive Outsourcing Pitfalls in Artificial Intelligence Education Application and its leapfrog. Research on Audio-Visual Education, 2023, 44(12): 5-13.
[42] Lu Daokun, Chen Jiyu. Sora: "Rescuer" or "Terminator" of school education. Journal of Xinjiang Normal University (Philosophy and Social Sciences Edition), 2024, 45(06): 112-127+2.
[43] Wang Yiyan, Liu Qi, Zheng Yonghe. Man-machine collaborative learning: Practical logic and typical models. Open Education Research, 2024, 30(01): 65-72.

Eurasia Journal of Science and Technology
ISSN: 2663-1016
DOI: 10.61784/ejst3011

GENERATIVE ARTIFICIAL INTELLIGENCE TECHNOLOGY-BASED ARCHITECTURE FOR AN INTELLIGENT CAMPUS MANAGEMENT PLATFORM

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Abstract: Generative artificial intelligence technology represents a transformation approach to the design and implementation of intelligent campus management platforms. As educational institutions increasingly seek to optimize operations, enhance learning environments, and improve resource allocation, the integration of generative AI can facilitate these objectives by providing data-driven insights and automating complex processes. This innovative technology enables institutions to harness vast amounts of data generated within campus ecosystems, thereby allowing for more informed decision-making and personalized user experiences. The architecture of an intelligent campus management platform powered by generative AI typically encompasses several key components: data collection, processing, analysis, and visualization. By utilizing IoT devices and other data sources, campuses can collect real-time information on various parameters such as student attendance, resource usage, and environmental conditions. Smart campus refers to a new education model that uses information technology, data as the core, and network as the basis to achieve comprehensive intelligence in campus environment, resources, services, and management. In this paper, the development of generative AI technology is sorted out, while relevant algorithms and models are summarised in detail, a smart campus management architecture based on generative AI technology is proposed, and its application scenarios are preliminarily planned. The method proposed in this paper will effectively improve the current intelligent level of smart campus management, which has high practical significance and theoretical value.
Keywords: Generative Artificial Intelligence; Education; Smart campus

1 INTRODUCTION

Generative Artificial Intelligence (GAI) technology has been increasingly utilized in various fields, including energy optimization, drug discovery, and education management. Mills et al. proposed a Cloud Edge architecture that leverages AI and data analytics for microgrid energy optimization and achieving net zero carbon emissions[1]. With the rapid development of the Internet, Internet of Things, big data, artificial intelligence and other technologies, the education industry is experiencing unprecedented changes, and smart campus, as an advanced stage of education informatisation, has become an important trend in the development of global education. This demonstrates the potential of AI technology in addressing complex challenges such as energy efficiency. Artificial intelligence systems, as discussed in the literature, involve advanced tools and networks that mimic human intelligence[2]. The architecture of AI systems plays a crucial role in their functionality and effectiveness. GAI, as explained by MIT News, is a powerful technology that has gained attention with the release of platforms like ChatGPT[3]. While generative AI is not entirely new, its applications continue to evolve and impact various industries. In the context of education management, generative AI technology has shown promise in empowering systems such as intelligent speech teaching system[4]. By leveraging natural language processing and generative AI, educational platforms can enhance the learning experience for students. Additionally, Siemens has accelerated its hydrogen ramp-up using generative AI software tools highlighting the potential of AI in optimizing industrial processes. Looking ahead, research will need to explore the evolving role of generative AI in AI platforms and technologies[5]. As AI continues to advance, understanding the implications and capabilities of generative AI will be essential for future developments. NIST has also released a draft publication on the AI Risk Management Framework to address the risks associated with generative AI technologies[6]. This framework aims to help organizations manage the potential risks and challenges posed by AI systems. In conclusion, generative AI technology has the potential to revolutionize various sectors, from energy management to education. By leveraging AI capabilities, organizations can optimize processes, enhance decision-making, and drive innovation in their respective fields. As research and development in AI continue to progress, understanding the architecture and applications of generative AI will be crucial for unlocking its full potential[7].

Education as one of the typical scenarios of AIGC technology landing, during 2023, a total of 45 investment and financing occurred in the global AIGC+ education track, half of which originated from the United States, and most of them are concentrated in the two sub-fields of K12 education and vocational training, as in figure 1. From the point of view of project maturity, the current AIGC+ education investment and financing is concentrated in the early stage, the global capital is generally concerned with a small amount of capital layout of early stage entrepreneurial projects.

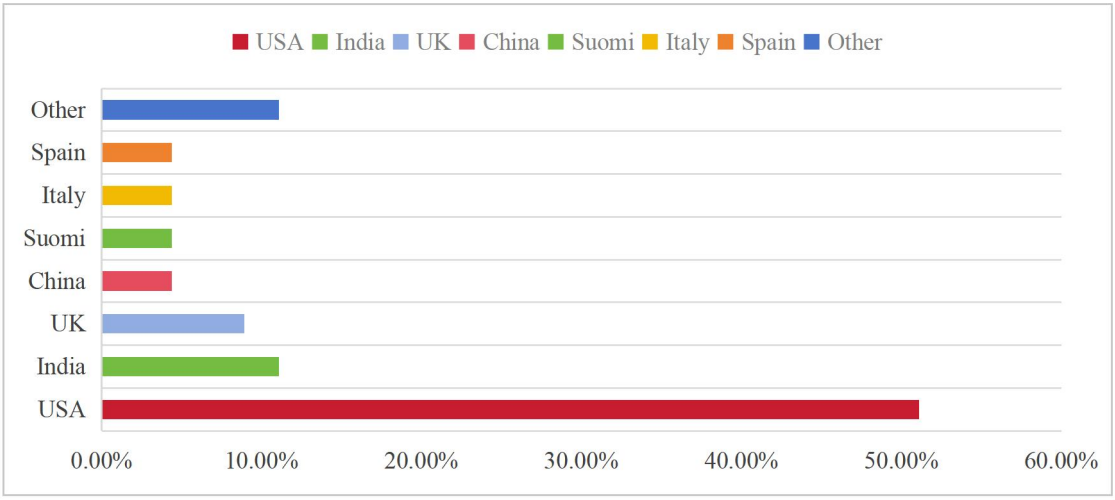

Figure 1 Global AIGC+ education investment and financing (2023)

Although there are fewer mature projects at present, compared with seed and angel rounds, the single financing amount of VC is higher. It can be predicted that with the application of AIGC in the field of education development towards maturity, capital will cut into the mature, high-quality project attention, as in figure2.

The technological frontier of GAI will move in the following four directions. **Multimodal Macromodelling.** From the human perspective, human intelligence is naturally multimodal, with humans possessing eyes, ears, nose, tongue, body and mouth (language), and from the AI perspective, vision, hearing, etc. can also be modelled as sequences of tokens, which can be learnt in the same way as the big language model, and further aligned with the semantics in the language, to achieve multimodal-aligned intelligence capabilities[8-9]. **Big Model of Video Generation**. OpenAI releases SORA, a Vincennesian video model, in February 2024, which dramatically increases the duration of video generation from a few seconds to one minute, with significant improvements in resolution, picture realism, timing consistency, etc[10]. The great thing about SORA is that it possesses the basic features of the world model, i.e., the ability of human beings to observe the world and then to further predict the world. The world model is based on understanding the basic physics of the world (e.g., water flows downhill, etc.) and then observing and predicting what events will happen next. Although there are still many problems for SORA to become a world model, it can be assumed that SORA learns the picture imagination and minute future prediction abilities that are foundational characteristics of a world model[11]. **Embodied Intelligence.** Embodied intelligence refers to intelligent bodies that have a body and support interaction with the physical world, such as robots and unmanned vehicles, etc[12]. The multimodal macromodel handles multiple sensor data inputs, and the macro-model generates motion commands to drive the intelligent body, replacing the traditional rule- or mathematical formula-based motion drive method, and realising the deep fusion of the virtual and the real[13-14]. Therefore, robots with embodied intelligence can gather the three major schools of AI: Connection represented by neural networks, symbolism represented by knowledge engineering and cybernetics-related behaviourism, and the three major schools can act on a single intelligence at the same time, which is expected to lead to new technological breakthroughs. **AI for Research.** Currently, scientific discovery mainly relies on experiments and human brain intelligence, with humans making bold conjectures and carefully seeking proofs, and information technology, both in terms of computation and data, only plays a role in assisting and verifying[15]. Compared with human beings, artificial intelligence has a greater advantage in memory, high-dimensional complexity, full field of vision, depth of reasoning, conjecture, etc[16]. Whether it is possible to make some scientific discoveries and technological inventions mainly by AI, and significantly improve the efficiency of human scientific discoveries, such as active discovery of the laws of physics, prediction of protein structure, design of high-performance chips, and highly efficient synthesis of new drugs[17-18]. Because the AI big model has a full amount of data, with God's perspective, through the ability of deep learning, can be more steps forward than a person, such as can be achieved from the inference (inference) to the reasoning (reasoning) of the leap, generative AI model has the potential to have the same Einstein's imagination and scientific conjecture ability, greatly enhance the efficiency of human scientific discovery, break the the boundaries of human cognition[19].

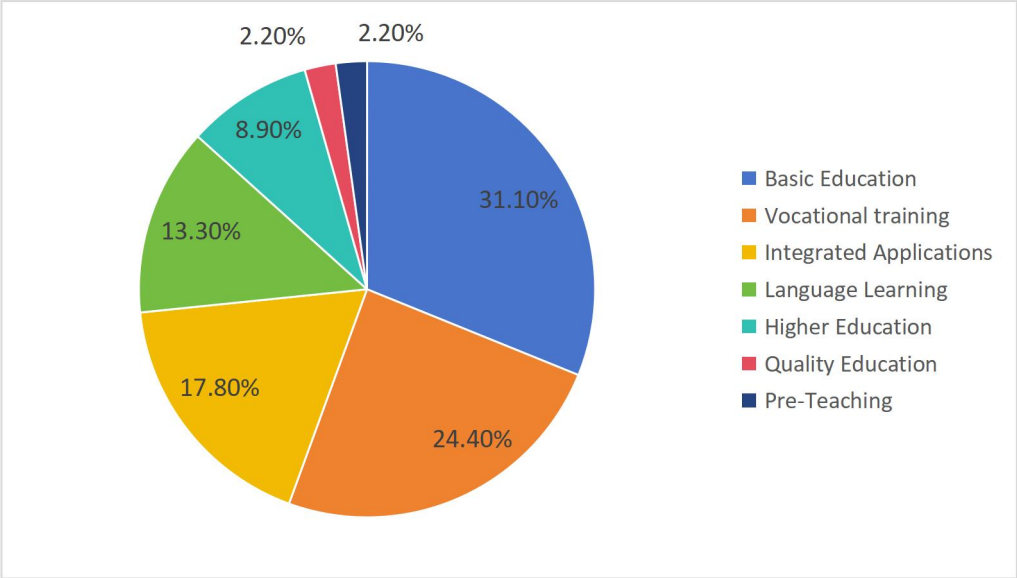

Figure 2 Global AIGC+ education investment and financing segmentation (2023)

Furthermore, the utilization of generative AI algorithms in educational settings can also facilitate personalized learning pathways, adaptive assessments, and data-driven decision-making processes to further enhance the effectiveness of academic programs. Additionally, the incorporation of generative AI algorithms in educational settings enables institutions to customize learning pathways for individual students, implement adaptive assessments to monitor progress, and utilize data-driven approaches for decision-making, thereby maximizing the efficacy of academic programs. Moreover, the integration of generative AI algorithms in educational settings allows for the customization of learning pathways tailored to the specific needs of individual students, the implementation of adaptive assessments for ongoing monitoring of progress, and the utilization of data-driven approaches for decision-making, thereby maximizing the efficacy of academic programs.

The paper is organised as follows. Chapter 1 gives the background of the study. Chapter 2 provides an analysis of the application of generative AI techniques in education. Chapter 3 proposes a smart campus management architecture based on generative AI technology. Chapter 4 provides a preliminary planning of the applications based on the architecture proposed in the previous chapter.

2 GENERATIVE ARTIFICIAL INTELLIGENCE TECHNIQUES IN SMART CAMPUS

GAI technology has emerged as a transformative force in various sectors, including education. The integration of GAI into campus management systems presents an innovative approach to enhance the operational efficiency and user experience of educational institutions. By leveraging machine learning algorithms and data analytics, an intelligent campus management platform can be developed to streamline administrative tasks, optimize resource allocation, and improve communication between stakeholders. One of the primary benefits of employing GAI in campus management is its ability to analyze vast amounts of data generated by students, faculty, and staff. Through predictive analytics, institutions can anticipate enrollment trends, identify at-risk students, and allocate resources accordingly. This proactive approach not only enhances academic performance but also fosters a supportive learning environment that addresses individual needs. Furthermore, GAI can facilitate personalized learning experiences by tailoring educational content based on student preferences and performance metrics. Moreover, the implementation of generative AI technologies can significantly enhance facilities management within campuses. Smart algorithms can monitor energy consumption patterns, predict maintenance needs for infrastructure, and optimize space utilization in real-time. This results in cost savings for institutions while promoting sustainability through more efficient resource use. Additionally, integrating chatbots powered by GAI into campus services allows for 24/7 support for students and staff alike, thereby improving overall satisfaction with institutional services. In conclusion, the development of an intelligent campus management platform using generative artificial intelligence technology holds immense potential for enhancing educational environments. By harnessing data-driven insights and automating various administrative functions, institutions can create a more responsive and efficient ecosystem that prioritizes both academic success and operational excellence.

Internationally, organisations such as UNSECO and the European Union, and countries such as the United States, Japan, the United Kingdom, and Australia have paid attention to a series of changes and impacts that AIGC will have on education, and have issued relevant policies and initiatives to provide guiding recommendations for its application, as in Table 1. Focusing on the scenario, on the technical side, the Interim Measures for the Administration of Generative Artificial Intelligence Services released in July 23rd clarified the service specifications and supervision and inspection responsibilities at the technical and general application levels, and encouraged the innovative application research and development of AIGC services. On the education side, various policies in the past have continued to mention encouraging the exploration of the application and development of AI technology in education, and policies on the

technology side have combined to promote the positive and prudent landing of AIGC+ education.

Table 1 AIGC+ education-related policies and initiatives in key countries and organisations around the world

Country/Orgin	Department	Time	Policy	Main Course
UNSECO	UNSECO	2023.09	Guidelines for generative artificial intelligence in education and science[20]	Proposing the regulation of generative AI for educational purposes requires a series of steps and policy measures based on a human-centred approach to ensure its ethical, safe, fair and meaningful use.
European	European Parliament	2023.06	Artificial Intelligence Bill[21]	AI systems used in eight areas, including education and vocational training, are categorised as high-risk and are required to be registered in the EU database and assessed throughout their lifecycle. In addition, generative AI must comply with transparency requirements.
USA	Office of Educational Technology (OET)	2023.03	Artificial intelligence and the future of teaching and learning: insights and recommendations[22]	Describes the opportunities for using AI to improve education, as well as the challenges that will arise, and makes recommendations to guide further policy development.
China	Ministry of Science and Technology (MOST)	2023.07	Interim Measures for the Management of Generative Artificial Intelligence Services[23]	Encouragement of innovative applications, independent innovation of basic technologies, handling of training data in accordance with the law, accurate and clear labelling of data, etc.
Japan	Ministry of Education, Culture, Sports, Science and Technology (MEXT)	2023.07	Interim guidelines for the use of generative AI at the primary secondary level[24] & On the treatment of generative AI in university and high school teaching and learning[25]	Contains directions and considerations for the application of generative AI for primary and secondary schools as well as universities and high schools.
UK	Ministry of Education (MEC)	2023.10	Generative Artificial Intelligence in Education[26]	Setting out the Ministry of Education's position on the use of generative AI in education, the document contains the opportunities and challenges that generative AI presents to the education sector, recommendations for the effective use of AI, focusing on data privacy and intellectual property rights, and advocating for the development of future-proof knowledge and skills.
Australia	Ministry of Education (MEC)	2023.11	A Framework for Generative Artificial Intelligence in Australian Schools[27]	The framework is based on six guiding principles: teaching and learning, human and social well-being, transparency, equity, accountability, privacy, and security, and supports school leaders, teachers, support staff, service providers, parents, guardians, students, and policymakers.

This table shows the percentage of different countries in a given statistical category (unspecified). It can be seen that the United States of America (USA) has more than half of the share (51.10 per cent), followed by India (11.10 per cent) and the United Kingdom (8.90 per cent). China has the same percentage as Spain, Italy and Finland (Suomi) with 4.40 per cent. The Other category accounted for 11.10 per cent of the share.

3 INTELLIGENT CAMPUS MANAGEMENT PLATFORM ARCHITECTURE BASED ON GENERATIVE ARTIFICIAL INTELLIGENCE TECHNOLOGY

GAI technology has emerged as a promising tool for enhancing the efficiency and effectiveness of various applications, including campus management platforms. One potential application of generative AI in campus management platforms is the automated generation of personalized schedules for students based on their academic preferences and course requirements. By leveraging the power of generative AI, institutions can create intelligent systems that can automate various tasks, improve decision-making processes, and enhance overall user experience.

3.1 Generative Artificial Intelligence Algorithms

One of the key components of a generative AI-based architecture for an intelligent campus management platform is the use of machine learning algorithms to analyze large amounts of data and generate insights that can inform

decision-making processes. These algorithms can be trained on historical data to identify patterns, trends, and anomalies, which can then be used to optimize resource allocation, improve student services, and enhance operational efficiency.Another important aspect of a generative AI-based architecture for a campus management platform is the integration of natural language processing (NLP) technology. NLP allows the system to understand and process human language, enabling users to interact with the platform in a more natural and intuitive way. This can improve communication between students, faculty, and administrators, and streamline various administrative processes.Furthermore, the use of generative AI technology can enable the development of personalized learning experiences for students. By analyzing individual learning styles, preferences, and performance data, the system can recommend tailored educational resources, courses, and activities that can help students achieve their academic goals more effectively.Overall, a generative AI-based architecture for an intelligent campus management platform has the potential to revolutionize the way educational institutions operate and deliver services. The current mainstream generative AI algorithms are shown in Table 2.

Table 2 Mainstream GAI algorithms

Algorithm	Time	Meaning	Main Features
VAEs[28]	2013	VAEs are generative algorithms based on probabilistic generative models that map the input data to a Gaussian-distributed latent space and then generate new data by sampling from the latent space.	**Interpretability:** VAE is able to explain the probability distribution of the generated data, which helps to understand the intrinsic structure of the data. **Flexibility:** VAE can be applied to a wide range of data types such as images, audio, text, etc. **Efficient:** The training process of VAE is relatively efficient and can generate a large amount of data quickly.
GANs[29]	2014	GANs consist of a generator network, which is responsible for generating fake data samples, and a discriminator network, which is responsible for distinguishing real data from fake data. By means of adversarial training, the generators are continuously improved to deceive the discriminators, and the discriminators are continuously improved to better distinguish the real from the fake.	**Autonomy:** GAN does not need to set the distribution of generated data artificially, but automatically finds a better generation strategy through adversarial learning. **Diversity:** the data generated by GAN has rich diversity and can generate various types of data. **High fidelity:** the data generated by GAN has high fidelity and is close to the real data.
RNNs[30] LSTM[31]	1996 1997	RNNs are a class of classical generative models capable of processing sequential data, such as text or time-series data. Through continuous iteration, RNNs are able to excel in generating text, music, etc. LSTMs are a variant of RNNs specifically designed to solve the long-term dependency problem.	**Memory function:** RNNs have a memory function that enables them to take contextual information into account when processing sequential data. **Long-term dependencies:** LSTMs control the flow of information by introducing gating mechanisms (forgetting gates, input gates and output gates) to learn long-term dependencies more effectively. **Widely used:** RNNs and LSTMs are widely used in the field of NLP for tasks such as language modelling, machine translation, sentiment analysis, and also for the prediction of time-series data, such as stock price prediction and weather prediction.
Transformer[32]	2017	Transformer is a model based on a self-attentive mechanism, which, unlike traditional models based on a recurrent structure, can process input sequences in parallel, thus offering advantages in training and inference speed.	**Parallel Processing:** Transformer is able to process input sequences in parallel to improve computational efficiency. **Self-attention mechanism:** The dependencies between sequence data are modelled through the self-attention mechanism to achieve more efficient computation. **Widely used:** Transformer has achieved great success in the field of NLP, especially in tasks such as machine translation, text classification, and named entity recognition.

By harnessing the power of AI technology, institutions can create more efficient, responsive, and student-centric environments that foster innovation, collaboration, and continuous improvement. Moreover, the integration of

generative AI algorithms in educational settings can lead to the creation of adaptive learning environments that cater to the diverse needs and abilities of students, ultimately enhancing the overall educational experience. Consequently, the implementation of generative AI algorithms in educational settings has the capacity to enhance student engagement, improve learning outcomes, and optimize the educational experience for all stakeholders involved in the academic process.The current mainstream generative multimodal large models are shown in Table 3.

Table 3 Mainstream GAI multimodal large models

Model	Time	Meaning	Main Features
GPT-Series[33]	2021	The GPT family of models, developed by OpenAI, is a pre-trained language model based on the Transformer structure. By pre-training on massive text data, GPT is able to understand and generate natural language text with strong context-awareness. It includes GPT-1, GPT-2, GPT-3 and the subsequent GPT-4.	The GPT family of models is widely used in many fields such as natural language processing, question and answer systems, text generation, etc., and is capable of generating high-quality textual content such as articles, poems, dialogues, and so on.
DALL-E[34]	2021	DALL-E is another generative big model developed by OpenAI, focusing on the field of image generation. It is capable of generating image artefacts corresponding to a short textual description entered by the user.	The images generated by DALL-E are of high quality and creativity, capable of capturing key information in text descriptions and transforming them into vivid image content.DALL-E has a wide range of applications in art creation, design, advertising and other fields, and provides creators with a brand new source of inspiration and creative tools.
Stable Diffusion[35]	2022	Stable Diffusion is another popular image generation model, similar to DALL-E, but it uses a different technical route and training strategy.	The images generated by Stable Diffusion are also of high quality and versatility to meet the needs of different users. Stable Diffusion has a wide range of potential applications in the fields of image creation, virtual reality, augmented reality, etc., providing strong support for the development of related fields.
Imagen[36]	2023	Imagen is an image generation model developed by Google, similar to DALL-E and Stable Diffusion, but with its own unique features and advantages.	Imagen generates images that excel in detail and fidelity, and is capable of producing high-quality, high-resolution image artwork.Imagen has a wide range of applications in a variety of fields, such as advertising, design, entertainment, etc., and provides an efficient and convenient image generation solution for related industries.
Sora[37]	2024	The Sora model is a state-of-the-art text-to-video generation model developed by OpenAI, based on the diffusion transformer architecture, a deep learning model that gradually transforms random noise into meaningful image or video content.	The Sora model is capable of generating videos up to one minute long that are not only of high visual quality, but also highly consistent with the user's text prompts. Combining a diffusion model and a converter architecture, video training is achieved in three steps: video compression network, temporal patch extraction and video generation.

The above are the current mainstream generative macromodels, which have achieved remarkable results in their respective fields and driven the continuous development of generative AI technology. With the continuous progress and innovation of technology, more generative big models with excellent performance and wide application will emerge in the future.GAI algorithms then analyze this data to identify patterns and correlations that may not be immediately apparent. Consequently, administrators can utilize these insights to make strategic decisions that enhance operational efficiency while simultaneously fostering a more engaging learning environment. Moreover, the adaptability of generative AI allows for continuous improvement in campus management systems. As new data is integrated into the platform over time, AI models can evolve to reflect changing circumstances or emerging trends. This dynamic capability ensures that educational institutions remain agile in their responses to challenges such as fluctuating enrollment numbers or shifting pedagogical approaches. Ultimately, the application of generative artificial intelligence technology in campus management not only streamlines administrative functions but also contributes significantly to the overarching goal of creating a responsive and intelligent educational ecosystem.

3.2 Intelligent Campus Management Platform

In recent years, there has been a growing interest in the development and implementation of intelligent campus management platforms in educational institutions. These platforms leverage advanced technologies such as artificial intelligence, machine learning, and data analytics to streamline various campus operations and enhance the overall student experience.One of the key benefits of an intelligent campus management platform is its ability to automate routine administrative tasks, such as class scheduling, resource allocation, and student enrollment. By reducing the time and effort required to perform these tasks manually, these platforms enable administrative staff to focus on more strategic initiatives that can improve the overall efficiency and effectiveness of the institution.Furthermore, intelligent campus management platforms can also provide valuable insights into student behavior and performance through the analysis of data collected from various sources, such as attendance records, academic performance, and extracurricular activities. By leveraging this data, institutions can identify at-risk students, personalize learning experiences, and improve student outcomes.Another advantage of intelligent campus management platforms is their ability to enhance communication and collaboration among students, faculty, and staff. These platforms often include features such as online forums, messaging systems, and collaborative tools that facilitate seamless communication and information sharing, leading to a more connected and engaged campus community. The smart campus architecture based on generative AI technology is shown in Figure 3.

The Smart Campus architecture based on Generative Artificial Intelligence (Gen AI) technology is a highly integrated and intelligent educational environment that aims to improve the efficiency and quality of all aspects of teaching, management, services and safety and security through AI technology. A smart campus architecture typically consists of four main layers: the perception layer, the network layer, the platform layer, and the application layer, which collaborate with each other to support the operation of the smart campus.

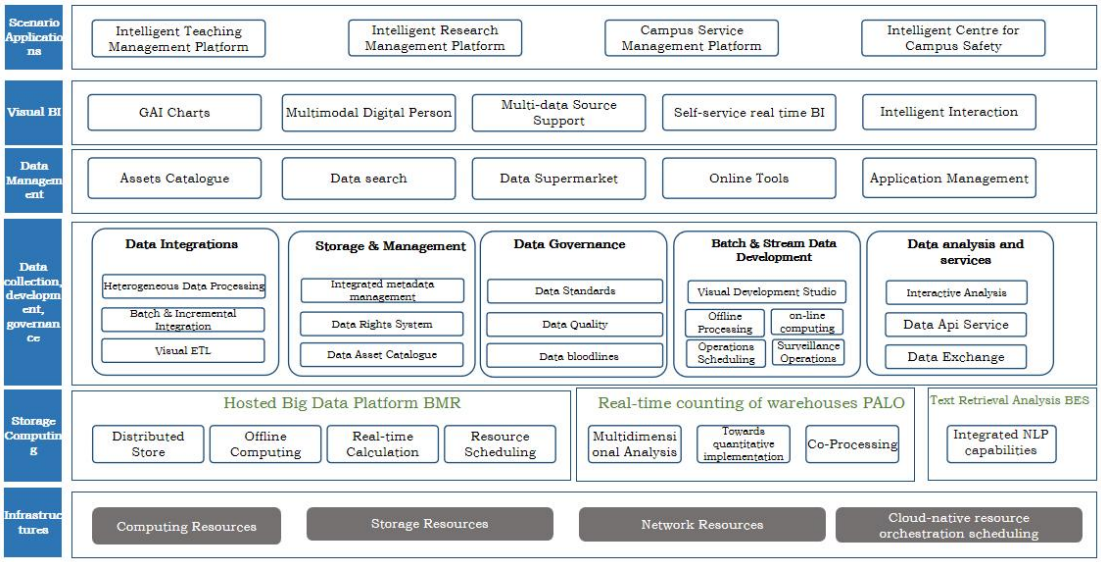

Figure 3 Intelligent campus management platform architecture based on generative artificial intelligence technology

Sensing Layer. Collect information on physical, chemical or biological quantities in the campus, such as students' attendance, equipment status, environmental parameters, etc. through various types of sensors, RFID, GPS, cameras and other devices.

Network Layer. Build a high-speed and stable campus network to realise real-time transmission and sharing of information, including wired network, wireless network, mobile Internet and other forms of network.

Platform layer. including infrastructure platform and support service platform. The infrastructure platform is responsible for computing, storage and backup services; the support service platform provides data processing, middleware services and database services to achieve centralised, scale management and dynamic flow of resources.

Application Layer. Provides all kinds of intelligent services for campus users, including teaching management, student services, security management, energy management and other aspects.

Overall, the implementation of an intelligent campus management platform can significantly improve the efficiency, effectiveness, and overall experience of students, faculty, and staff in educational institutions. As technology continues to advance, it is likely that these platforms will play an increasingly important role in shaping the future of higher education. Furthermore, the integration of artificial intelligence and machine learning algorithms within these platforms allows for predictive analytics and data-driven decision-making, enabling institutions to proactively address issues and provide targeted support to individuals based on their unique needs and behaviors. Moreover, the utilization of data analytics and artificial intelligence within intelligent campus management platforms can also lead to personalized learning experiences and tailored interventions for students, thereby enhancing student success and retention rates in educational institutions.

4 KEY TECHNOLOGIES AND APPLICATIONS OF GAI-BASED SMART CAMPUS

Smart campus construction based on GAI technology is an important trend in the current education field. Generative AI technology, with its powerful data generation, analysis and processing capabilities, provides strong technical support and innovative power for the construction of smart campuses.

Personalized teaching. By analysing students' learning behaviours and outcomes, Gen AI technology is used to generate personalised learning paths and resources to improve teaching effectiveness and learning efficiency. For example, AI can assist teachers in designing questions to stimulate students' critical and creative thinking; in essay correction, AI can provide evaluation and revision suggestions to help teachers conduct diversified evaluations.

Intelligent management. In campus management, Gen AI can assist in data analysis, decision support, resource scheduling and other tasks. For example, when selecting school managers, AI can comprehensively analyse the data and situation of the candidates and provide decision-making support for the managers; in safety management, AI can monitor the campus safety situation in real time, predict potential risks and intervene in advance.

Resource optimization. through Gen AI technology, smart campuses can achieve optimal allocation and sharing of educational resources. For example, AI can analyse students‘ learning needs and ability levels, and extract personalized learning content from the resource library that meets students’ characteristics; at the same time, AI can also promote cooperation and communication with external resources to achieve the sharing and optimal allocation of educational resources.

Intelligent services. In the smart campus, Gen AI technology can also be applied to various intelligent service scenarios. For example, the smart library system can use AI technology to realize automatic classification, retrieval and recommendation of books; and the smart one-card system can realize the seamless connection and unified management of all kinds of consumption and services on campus.

The construction of smart campuses based on generative AI technology is an important change in the field of education. Through the application of personalized teaching, intelligent management, intelligent assessment and feedback, and intelligent service and protection, smart campuses will provide students and teachers with a better, more efficient and convenient educational environment and service experience. However, in the process of promoting the construction of smart campuses, it is also necessary to pay attention to issues such as technological challenges, funding and resource challenges as well as teacher qualification and training challenges, and take corresponding measures to solve them.

5 SUMMARY

With the continuous development and maturity of generative AI technology, the construction of smart campuses will focus more on personification, intelligence and openness. In the future, the smart campus will pay more attention to the personalized development of students, and provide more accurate learning paths and resources for each student through AI technology; at the same time, the smart campus will also strengthen cooperation and communication with external resources to achieve the sharing and optimal allocation of educational resources; in addition, with the continuous progress of technology and the continuous expansion of application scenarios, the smart campus will provide students and teachers with a more convenient, efficient, intelligent learning and management experience. In short, the smart campus architecture based on generative AI technology is a highly integrated and intelligent educational environment, which will provide teachers and students with more quality educational resources and service experiences, and promote the sustainable development and progress of education.In this paper, the development of generative AI technology is sorted out, while relevant algorithms and models are summarized in detail, a smart campus management architecture based on generative AI technology is proposed, and its application scenarios are preliminarily planned. The method proposed in this paper will effectively improve the current intelligent level of smart campus management, which has high practical significance and theoretical value.

FUNDING

This work is partially supported by 2023 Shenzhen Education Science Planning Project "Research on the Mechanisms and Strategies of Cross-border Co-operation in the Industry-Teaching Integration Community of Vocational Undergraduate Colleges and Universities (yb23048)", 2024 Shenzhen Polytechnic University Quality Engineering Project "Research on Classroom Scene Understanding and Behavior Analysis Method Based on Multimodal Attention Mechanisms (7024310268)", 2023 Guangdong Provincial Higher Vocational Education Teaching Reform Research and Practice Project "Research on Online Teaching Quality Evaluation Method Based on Multimodal Affective State Analysis (7024320403)".

COMPETING INTERESTS

The authors have no relevant financial or non-financial interests to disclose.

REFERENCES

[1]Mills N., Rathnayaka P., Moraliyage H., De Silva D., Jennings A. "Cloud Edge Architecture Leveraging Artificial Intelligence and Analytics for Microgrid Energy Optimisation and Net Zero Carbon Emissions," 2022 15th

International Conference on Human System Interaction (HSI), Melbourne, Australia, 2022: 1-7. DOI: 10.1109/HSI55341.2022.9869465.
[2]Paul D, Sanap G, Shenoy S, Kalyane D, Kalia K, Tekade RK. Artificial intelligence in drug discovery and development. Drug Discov Today, 2021, 26(1): 80-93. DOI: 10.1016/j.drudis.2020.10.010. Epub 2020 Oct 21. PMID: 33099022; PMCID: PMC7577280.
[3]Dwivedi Y K, Kshetri N, Hughes L, et al. Opinion Paper: "So what if ChatGPT wrote it? " Multidisciplinary perspectives on opportunities, challenges and implications of generative conversational AI for research, practice and policy. International Journal of Information Management, 2023, 71: 102642.
[4]Wach K, Duong C D, Ejdys J, et al. The dark side of generative artificial intelligence: A critical analysis of controversies and risks of ChatGPT. Entrepreneurial Business and Economics Review, 2023, 11(2): 7-30.
[5]Anonymous .Microsoft and Siemens Partner to Drive AI Adoption. Assembly, 2023, 65(12): 15-15.
[6]Kelley A. NIST's new AI safety institute to focus on synthetic content, international outreach. Nextgov.com (Online), 2024.
[7]Andrea T A, Marçal C M, Carlos J N. How to teach responsible AI in Higher Education: challenges and opportunities. Ethics and Information Technology, 2023, 26(1).
[8]Sun H, Liu R, Cai W, et al. Reliable object tracking by multimodal hybrid feature extraction and transformer-based fusion. Neural Networks, 2024, 178106493-106493.
[9]Alf V, Tirrito F, Fischer A, et al. A multimodal approach to diagnosis of neuromuscular neosporosis in dogs. Journal of veterinary internal medicine, 2024.
[10]O'Callaghan J. How OpenAI's text-to-video tool Sora could change science - and society. Nature, 2024, 627(8004): 475-476.
[11]Beup E P A, Chan L J K, Dungca S A J, et al. Purchase in Petrol Service Stations Along Tandang Sora Avenue in Quezon City. Management, 2023, 6(2).
[12]Shen T, Sun J, Kong S, et al. The Journey/DAO/TAO of Embodied Intelligence:From Large Models to Foundation Intelligence and Parallel Intelligence. IEEE/CAA Journal of Automatica Sinica, 2024, 11(06): 1313-1316.
[13]Donghee S. Embodying algorithms, enactive artificial intelligence and the extended cognition: You can see as much as you know about algorithm. Journal of Information Science, 2023, 49(1): 18-31.
[14]David H. From the lab to the field with Evolutionary Field Robotics. Frontiers in Robotics and AI, 2022, 91027389-1027389.
[15]Almulla A M. Investigating influencing factors of learning satisfaction in AI ChatGPT for research: University students perspective. Heliyon, 2024, 10(11): e32220.
[16]Xu B, Chen S. Exploring the Impact of Artificial Intelligence Technology on Creative Challenges and Potential Breakthroughs: A Case Study of the TikTok Short Video Platform. Communication & Education Review, 2024, 5(3).
[17]Simon B. AI could be an opportunity for research managers. Nature, 2023.
[18]Dalmeet C S. AI system not yet ready to help peer reviewers assess research quality. Nature, 2022.
[19]Aubrey W, Carlos C, Axel M, et al. The impact of AI on research. Cell, 2022, 185(15): 2621-2622.
[20]Carl P, Christian R. Opportunities, Challenges, and Future Directions of Generative Artificial Intelligence in Medical Education: Scoping Review. JMIR medical education, 2023, 9e48785-e48785.
[21]Alms N. Democrats urge the White House to bind agencies to the AI Bill of Rights. Nextgov.com (Online), 2023.
[22]Kumari G S, Kumar D G, Prasad A Y. Analysis of ChatGPT and the future of artificial intelligence: Its effect on teaching and learning. Journal of AI, Robotics & Workplace Automation, 2024, 3(1): 64-80.
[23]Alavi M, Leidner E D, Mousavi R. Knowledge Management Perspective of Generative Artificial Intelligence. Journal of the Association for Information Systems, 2024, 25(1): 1-12.
[24]Cummings E R, Monroe M S, Watkins M. Generative AI in first-year writing: An early analysis of affordances, limitations, and a framework for the future. Computers and Composition, 2024, 71: 102827.
[25]Ogunleye B, Zakariyyah I K, Ajao O, et al. A Systematic Review of Generative AI for Teaching and Learning Practice. Education Sciences, 2024, 14(6): 636-636.
[26]Velasco S S, Rodríguez A M, Benito D V, et al. Analysing the Impact of Generative AI in Arts Education: A Cross-Disciplinary Perspective of Educators and Students in Higher Education. Informatics, 2024, 11(2): 37-37.
[27]Ayman A W. Drivers of generative artificial intelligence to fostering exploitative and exploratory innovation: A TOE framework. Technology in Society, 2023, 75.
[28]Membrane Proteins; New Findings from E. Vaes and Colleagues Has Provided New Data on G-Protein-Coupled Receptors. Information Technology Newsweekly, 2014, NewsRx.
[29]Xiao H, Wang X, Wang J, et al. Single image super-resolution with denoising diffusion GANS. Scientific reports, 2024, 14(1): 4272-4272.
[30]Cho K, Merrienboer V B, Gülçehre Ç, et al. Learning Phrase Representations using RNN Encoder-Decoder for Statistical Machine Translation. CoRR, 2014, abs/1406.1078.
[31]Deep sentence embedding using long short-term memory networks. IEEE/ACM Transactions on Audio, Speech and Language Processing (TASLP), 2016, 24(4).
[32]Khan Z M, Usman M, Ahmad J, et al. Tag-free indoor fall detection using transformer network encoder and data fusion. Scientific Reports, 2024, 14(1): 16763-16763.

[33]Bae J, Kwon S, Myeong S. Enhancing Software Code Vulnerability Detection Using GPT-4o and Claude-3.5 Sonnet: A Study on Prompt Engineering Techniques. Electronics, 2024, 13(13): 2657-2657.
[34]Mark A, Ehsan A, Ritsaart R, et al. Now you see me, now you don’t: an exploration of religious exnomination in DALL-E. Ethics and Information Technology, 2024, 26(2): 27.
[35]F. A D, Álvaro P, Luís M, et al. Acoustic imaging of stable double diffusion in the Madeira abyssal plain. Scientific Reports, 2024, 14(1): 8273-8273.
[36]Genç H, Tanrıverdi S, Şen M. Determinación de la imagen corporal y los niveles de autoeficacia en pacientes después de un trasplante de córnea. Enfermeria Clinica, 2024, 34(1): 49-55.
[37]O'Callaghan J. How OpenAI's text-to-video tool Sora could change science - and society. Nature, 2024, 627(8004): 475-476.

Eurasia Journal of Science and Technology
ISSN: 2663-1016
DOI: 10.61784/ejst3012

THE BUSINESS OF WAR: A STUDY ON THE THREAT PERCEPTION MECHANISM OF THE EUROPEAN MILITARY-INDUSTRIAL COMPLEX

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Abstract: European defense spending has risen significantly, particularly since the Russia-Ukraine conflict. This study investigates the role of the military-industrial complex in this trend. Using data from 2010-2022, it finds that the military-industrial complex influences threat perception and defense spending. It exaggerates external threats, creating a security agenda that benefits its own interests. Countries with greater military-industrial complex influence exhibit higher threat perception and increased defense spending. This "creating demand" logic differs from traditional arms procurement and highlights the military-industrial complex's agency in shaping the security agenda. Countries should be vigilant about the influence of military-industrial interest groups on defense policies to avoid over-allocation of defense resources due to manipulated threat perceptions.
Keywords: Europe; Military-industrial complex; Threat perception; Defense spending

1 INTRODUCTION

On February 24, 2022, the Russia-Ukraine conflict erupted, profoundly impacting the geopolitical and military security situation in Europe. On one hand, Russia's military actions have exacerbated the objective security threats faced by European countries, prompting NATO and the EU to accelerate the development of their military capabilities. On the other hand, the Russia-Ukraine conflict has also fundamentally reshaped the subjective threat perceptions of European nations, reshaping policy agendas surrounding defence development and military expenditure. Against this backdrop, the military-industrial complexes of European countries, as special interest groups that match military equipment needs with defence resource allocation, have increasingly become a critical force influencing regional military games and strategic competition.

The military-industrial complex refers to the intricate network of interests among the military, government, and defence industries, which significantly influences a country's military, political, and economic decision-making [1]. For a long time, the European military-industrial complex has played an important but not always positive role in driving regional military modernization and shaping the causes of war. After the Cold War, defence budget cuts in the context of the "peace dividend" once led to the contraction of the European defence industry and the decline of interest groups [2]. However, with the diffusion of the military technology revolution and the rise of terrorist threats in the 21st century, the European military-industrial complex has re-emerged, exerting substantial influence in areas such as defence procurement, civil-military integration, and foreign arms sales. The Russia-Ukraine conflict has further demonstrated that, catalysed by major geopolitical conflicts, the military-industrial complex is deeply involved in European countries' military strategies and budget planning by justifying situations, guiding policies, and securing resources.

In light of this, this paper focuses on the core issue of "how the military-industrial complex adjusts national threat perceptions and influences defence policies and military actions in the context of European geopolitical conflicts," conducting in-depth discussions from both theoretical and empirical perspectives. This paper hypothesizes that the military-industrial complex in European countries may influence threat perceptions and subsequently impact defense spending decisions, particularly in the context of the Russia-Ukraine conflict. We propose that European countries with a strong military-industrial complex may experience heightened threat perceptions due to the complex's influence, potentially leading to a greater increase in their defense spending. Conversely, European countries with a weaker military-industrial complex may have their threat perceptions less influenced by the complex, possibly resulting in a smaller increase in their defense spending. However, it is important to acknowledge that this hypothesized relationship between the military-industrial complex, threat perceptions, and defense spending is complex and multifaceted. While the military-industrial complex may attempt to influence government decision-making to increase defense spending, as evidenced by examples cited in the literature, governments must balance a variety of factors and competing influences when making spending decisions. The strength of the military-industrial complex's influence on threat perceptions and the subsequent impact on defense spending may vary across countries and contexts.

To substantiate this idea, this paper will analyze the changing trends in the military-industrial complex influence, threat perceptions, and defence spending of major European countries from 2010 to 2022, with a particular focus on changes before and after the 2014 Ukraine crisis and the 2022 Russia-Ukraine war. Additionally, the paper will select the military-industrial complexes of France, Germany, Poland, and the Czech Republic as case studies to empirically examine the key mechanisms by which these interest groups leverage major geopolitical frictions to influence defence

policies. This research will contribute to a deeper understanding of the varying reactions of European countries to the Russia-Ukraine conflict and provide a new perspective for comprehending the formulation of European security policies.

2 LITERATURE REVIEW

The concept of the military-industrial complex was first introduced by US President Dwight D. Eisenhower in 1961, when he warned that the growing interconnections between the military, government, and defence industries might have adverse effects on American democracy and economy [3]. Subsequently, scholars have explored the operating logic, influence mechanisms, and consequences of the military-industrial complex from political, economic, and social dimensions, leading to a wealth of theoretical and empirical research.

At the theoretical level, Steven Rosen [4], from an organizational theory perspective, pointed out that the military-industrial complex is an interest community composed of multiple bureaucratic organizations, with the goal of maintaining and expanding military budgets. Seymour Melman [5], from a Marxist viewpoint, argued that its essence is a product of monopoly capitalism, a tool for the capitalist class to control state power and pursue profits. Henry A. Giroux [6] further situated the military-industrial complex in the context of neoliberal globalization, arguing that it has evolved into a transnational network that promotes global militarization by manipulating fear and insecurity. However, some scholars contend that the influence of the military-industrial complex is relatively limited, and government decisions are primarily based on competition with other states and the need to win or at least survive warfare [7]. These divergent perspectives reflect the ongoing debates within the academic literature on the role and impact of the military-industrial complex.

In empirical research, scholars have employed various methods, such as econometric analysis, social network analysis, and case studies, to examine the impact of the military-industrial complex on national policies and international relations. One important research theme is the relationship between the military-industrial complex and defence spending. Studies have shown that defense companies influence political decisions through campaign contributions and lobbying activities, leading to increases in military budgets [8]. Research across various countries has shown a complex relationship between defense companies' profit rates and defense spending, suggesting the military-industrial complex's role in driving military expenditure growth [9]. However, some studies argue that the influence of the military-industrial complex on defence spending is overstated, and governments must balance various interests and factors when making budgetary decisions [10-11].

Another key research theme is the shaping of threat perceptions and security policies by the military-industrial complex. During the Cold War, the complex exaggerated the Soviet military threat to justify military build-up, as seen in the manufactured "missile gap" crisis. Post-Cold War, it redefined security threats to expand the US global military presence. This influence extends globally, interacting with geopolitical factors and nationalism to drive militarization processes worldwide [12]. However, some scholars argue that the military-industrial complex's influence on threat perceptions and security policies is limited, as governments must consider a wide range of factors, including strategic autonomy and the complexity of balancing multiple interests [13-14].

Research on the European military-industrial complex post-Cold War has highlighted the impact of cross-border mergers and industrial consolidation on defense companies, leading to increased influence on European security policies. European defense companies actively participate in shaping defense agendas and military capability development through involvement in EU research projects and think tank networks [15]. Nevertheless, the influence of the military-industrial complex might undermine the EU's strategic autonomy, making it difficult to make independent judgments when responding to external threats [16]. Large corporations, including British American Tobacco, have been observed influencing policy-making within the EU, potentially affecting decisions related to defense and industrial spending [17]. However, these studies rarely systematically compare the differences in the influence of the military-industrial complexes across European countries and how these differences affect each country's perception and reaction to external threats. Given the uneven development of the defence industries in European countries and their complex interactions with the US military-industrial complex, this issue has become more urgent and important in the current context of the Russia-Ukraine conflict.

In summary, the academic community has accumulated a wealth of theoretical and empirical research on the military-industrial complex, providing important references for understanding its operating mechanisms and consequences. However, existing research on the European military-industrial complex still has many shortcomings. Most literature focuses on the development of defence companies and civil-military integration policies, with insufficient attention paid to the political influence of the military-industrial complex. Although some scholars have explored the role of defence interest groups in promoting defence spending, their analyses are mainly limited to single-country case studies [18]. Systematic analyses of how the military-industrial complex adjusts national threat perceptions and shapes regional security situations at the macro level are relatively weak. In particular, there is a lack of research that adopts a comparative perspective to reveal the differences in the influence of the military-industrial complexes across European countries and the driving mechanisms behind these differences in the context of a dynamically changing geopolitical landscape.

Building on previous studies, this research aims at making academic contributions in the following aspects. First, by systematically measuring and comparing the influence of the military-industrial complexes in European countries, it provides empirical evidence to reveal their internal differentiation. Second, it explores the role of the military-industrial

complex in shaping threat perceptions, enriching the understanding of its influence mechanisms. Third, by examining the military-industrial complex in the dynamic context of the Russia-Ukraine conflict, it enhances the relevance and practical applicability of theoretical explanations. The purpose of this research is to contribute to the theoretical development of the military-industrial complex and provide new analytical perspectives for understanding the complexities of European security policies.

3 THEORETICAL ANALYSIS

3.1 Threat Magnification: The Military-Industrial Complex's Shaping of National Security Perceptions

The military-industrial complex, as an important force in the modern national military-political structure, has a significant impact on national security policies that cannot be ignored. Particularly in the formation of national threat perceptions, the military-industrial complex often plays a crucial role in shaping these perceptions. Firstly, as a pressure group with special interest demands, the political influence of the military-industrial complex is often exercised with national security issues as the entry point. By leveraging its professional advantages in military technology and intelligence, the military-industrial complex occupies a favorable position in the agenda-setting and policy debates related to national security, thus influencing the subjective perception of external threats among decision-makers and the public [19]. Furthermore, the economic power of the military contributes to its political influence, providing increased capital for the armed forces and reinforcing its role in shaping national security discourse [20]. This influence is formalized through institutions like the National Security Council, which plays a key role in determining state security policies and further solidifying the military-industrial complex's impact on national threat perceptions [21].

Secondly, from a constructivist security theory perspective, the perception of external threats by nations is fundamentally a subjective construction process, rather than a simple reflection of objective conditions. When recognizing the external world, a nation is not a rational, unified actor, but a complex organizational machine and policy network that is inevitably influenced by factors such as military-political elite preferences and bureaucratic political struggles [22]. In this process, the military-industrial complex, as a policy actor with unique organizational interests and discursive power, often plays a key role in the production of national security discourse. By selectively magnifying specific security issues and strategically defining threat sources, the military-industrial complex deliberately shapes a tense international security context, thereby influencing the prioritization of national security policies. The military-industrial complex significantly influences national security policies by defining threat sources and shaping security discourse [23].

Thirdly, as a bureaucratic organization pursuing its own interests, the organizational inertia and path dependency of the military-industrial complex subtly influence the nation's threat perception. Factors such as the Cold War legacy has shaped the organizational thinking and behavioral patterns of the military-industrial complex, which relies heavily on external threats [24]. To obtain more arms procurement orders and research and development budgets, military enterprises and related interest groups tend to selectively assess and address external security situations, magnify military threats, and perpetuate the logic cycle of "threat-arms buildup[25]".Over time, this threat-oriented organizational inertia gradually institutionalizes into a solidified threat discourse, limiting and predisposing the nation's perception framework and response patterns towards the external world. It can be said that under the impetus of the military-industrial complex's organizational behavior inertia, national threat perception inevitably presents a self-reinforcing tendency.

In the context of European military policy in the post-Cold War era, the above theoretical logic of the military-industrial complex influencing national threat perceptions has been somewhat confirmed. On the one hand, the profound changes in the European geopolitical environment after the Cold War have objectively weakened the actual military threats faced by European countries, providing a realistic basis for the construction of threat discourse by the military-industrial complex [26]. On the other hand, with the gradual release of peace dividends, the European military industry feels the pressure of development and increasingly relies on highlighting regional security threats to compete for military orders, adopting more aggressive discourse strategies and lobbying methods [27]. In addition, since the 21st century, regional conflicts and terrorist threats have been frequent in Europe, objectively providing the military-industrial complex with favorable opportunities and discourse resources for implementing threat mobilization [28]. It can be said that the military-industrial complex, through discourse shaping, has to some extent magnified and extended European countries' threat perceptions of regional security situations and sought more organizational benefits.

In summary, the influence level of the military-industrial complex significantly moderates the impact of objective military threats on national subjective threat perceptions. Through carefully designed discourse strategies and organized political mobilization, the military-industrial complex has greatly magnified national subjective threat assessments of the external world, profoundly affecting the formulation and implementation of national security policies. This influence is particularly prominent in the post-Cold War era. Therefore, systematically examining the constructive effects of the military-industrial complex on national threat perceptions is of great theoretical significance for understanding the power operation of contemporary military-political patterns and provides important practical reflections for reconsidering the disorderly expansion of military-industrial interests.

3.2 Perception Differences and Military Expenditure Bargaining: How Threat Perceptions Influence Defense Spending

The differences in threat perceptions among nations and their impact on defense expenditures have long been an important issue in security studies. As a crucial cognitive variable linking a nation's security environment and military policies, threat perception largely determines the direction of military force development and the level of resource allocation. Based on their respective geopolitical circumstances, historical experiences, and strategic cultures, different nations exhibit significant variations in perceiving and responding to external security threats, thereby shaping their military policies, particularly the diversity in defense spending scales and structures.

Firstly, from the perspective of the threat-balancing theory in realism, the objective military threats a nation faces are an important factor influencing its defense expenditures. In an anarchic state, to ensure its security and interests, a nation must determine its military force development goals and resource allocation based on the severity of external threats [29]. When a country faces an increased realistic military threat, its defense spending will inevitably rise to achieve a balance of military power. Conversely, when external military threats diminish, the country may reduce its defense budget for economic considerations [30]. In this sense, the differences in objective military threats among nations are a crucial starting point for understanding the variations in their defense spending levels. For countries geographically adjacent to hostile nations or embroiled in territorial disputes, higher realistic military threats often drive them to maintain relatively high levels of military expenditures. In contrast, for countries far from conflict hotspots and enjoying a stable security environment, lower external military threats limit their investments in the defense sector [31]. It can be argued that the differences in realistic military threats among nations, to a considerable extent, shape the structural differences in their defense spending levels.

Secondly, from the perspective of constructivist security perception theory, the subjective differences in nations' perceptions of external military threats are also a key factor influencing their defense expenditures. The constructivist view emphasizes that national security is not an objective fact but a complex social construction process, contingent upon the relevant actors' subjective interpretations of the security environment [32]. In this process, factors such as geopolitical identities, strategic cultural traditions, and historical lessons intertwine to shape a nation's perceptual framework of external security situations [33-34]. Therefore, despite facing similar objective military threats, different nations may form vastly divergent threat assessments, leading to differentiated military responses. Generally, nations with strong geopolitical identities and long-standing strategic cultural traditions, driven by their resolute commitment to sovereign integrity and territorial unity, tend to be more sensitive to external security threats. Consequently, they are more inclined to amplify threat perceptions subjectively and invest more resources in the defense sector [35-36]. Conversely, nations with weaker geopolitical identities and strategic traditions may underestimate external security situations and thus exercise relative restraint in military force development. Evidently, the differences in subjective threat perceptions are also a key variable influencing the variations in defense spending levels among nations.

Furthermore, from the perspective of organizational behavior theory, the differences in threat perceptions among a nation's administrative and military organizations further reinforce the diversity of its military policies and defense expenditures. A nation is not a unified rational actor but a complex organizational machinery comprising multiple interest groups [37]. In assessing external military threats, different systems, such as the military, diplomacy, and intelligence, often make different judgments based on their organizational interests and cognitive inertia [38]. Generally, the military, driven by the need to maintain its institutional interests, tends to exaggerate external military threats and advocate for more resource allocation to the defense sector. In contrast, departments such as diplomacy and finance, motivated by the need to maintain great power relations and balance budget expenditures, tend to adopt a more restrained assessment of military threats. The tension between these two types of departments in threat perception further shapes the policy balance in defense decision-making. The differences in domestic political mechanisms and power dynamics among nations contribute to the diverse preferences in military policies and the pluralistic differentiation in defense spending scales.

The above theoretical logic has been well reflected in the evolution of European countries' defense policies in the post-Cold War era. On one hand, after the dissolution of the Soviet Union, the geopolitical situation in Europe underwent profound changes, and the former "common enemy" disappeared, objectively reducing the realistic military threats faced by European nations. This change exerted a general downward pressure on European countries' defense expenditures, with most nations experiencing a noticeable decline in their military spending as a percentage of GDP [39]. On the other hand, European nations exhibited distinct characteristics in their subjective threat perceptions and military policy preferences. Eastern European nations, constrained by "post-communist" anxieties and sensitivity to Russian threats, generally held pessimistic views of the regional security situation. Consequently, they advocated offsetting geopolitical risks through measures such as increasing defense spending and strengthening NATO cooperation [40]. In contrast, Western European nations perceived regional threats more optimistically, believing that they should seize the strategic opportunity to shift resource allocation priorities from military defense to economic development. This difference in subjective perceptions directly influenced the defense investments of different nations and reinforced the asymmetric nature of European defense expenditures to a considerable extent.

Moreover, within major European powers, there were also notable policy tensions regarding the perception of military threats. Different departments, based on their respective organizational preferences, engaged in complex bargaining over issues such as the scale and structure of military expenditures, further accentuating the differences in European defense spending [41]. It is evident that the complex interplay between changes in objective military threats and differences in subjective threat perceptions profoundly shaped the pluralistic landscape of European nations' military policies and defense expenditures.

In summary, the differences in threat perceptions among nations are a key factor influencing the levels and structures of defense spending. These differences stem not only from the varying objective military threats nations face but also from their divergent subjective perceptions of external security situations, as well as the interest bargaining among different organizational departments in threat assessments. A systematic examination of the above theoretical logic contributes to revealing, from multiple perspectives, the mechanisms underlying the differences in nations' military policies and defense expenditures, thereby expanding the theoretical depth of security studies. Furthermore, an empirical examination of the evolution of European nations' military policies further highlights the importance of the threat perception perspective in understanding the differences in nations' military behaviors. Overall, incorporating the threat perception factor into the analytical framework of military policy analysis holds significant theoretical value for clarifying the complex political processes influencing nations' military force development and provides important analytical clues for reflecting on the risk mechanisms of regional arms races.

Based on the aforementioned theoretical analysis, the following core research hypotheses can be proposed to examine the moderating effect of the military-industrial complex's influence on threat perceptions and its policy implications:

H1: The influence of the military-industrial complex significantly moderates the impact of objective military threats on a nation's threat perceptions.

Specifically, in countries where the military-industrial complex wields stronger influence, the subjective threat perceptions regarding the objective military threat posed by the Russia-Ukraine conflict will be significantly amplified. In contrast, in countries where the military-industrial complex has weaker influence, the changes in subjective threat perceptions in response to similar objective military threats will be relatively limited.

H2: The military-industrial complex influences a nation's defense spending levels by shaping its threat perceptions.

Specifically, in countries where the military-industrial complex holds stronger influence, driven by amplified subjective threat perceptions following the outbreak of the Russia-Ukraine conflict, their increases in defense spending will be more pronounced. However, in countries where the military-industrial complex has weaker influence, with limited changes in subjective threat perceptions after the Russia-Ukraine conflict, their increases in defense spending will be relatively moderate.

Incorporating the influence of the military-industrial complex into the analytical framework of threat perceptions and defense spending helps deepen the understanding of interest groups' roles in the formation of military policies and enriches the explanatory power of relevant theoretical models. Additionally, by examining the moderating effects of the military-industrial complex on threat perceptions and policy shaping in different national contexts against the backdrop of the Russia-Ukraine conflict, this research holds important practical implications for clarifying the interest roots of regional military bargaining and reflecting on the governance boundaries of the military-industrial complex's influence.

4 QUANTITATIVE ANALYSIS

4.1 Model Specification

To test the research hypotheses, the following econometric models can be constructed:

To examine the moderating effect of the military-industrial complex's influence on threat perceptions (H1), the following multivariate linear regression model is constructed:

$$\text{Threat\_Perception} = \beta_0 + \beta_1\text{Threat} + \beta_2\text{MIC} + \beta_3\text{Threat}\times\text{MIC} + \gamma X + \varepsilon \quad (1)$$

Where Threat_Perception represents the level of subjective threat perception, Threat represents the level of objective military threat, MIC represents the influence level of the military-industrial complex, Threat×MIC is the interaction term, X represents control variables, and ε is the random disturbance term.

To test the mediating effect of the military-industrial complex influencing defense expenditures through shaping threat perceptions (H2), the following mediation model is constructed:

Estimating the total effect of the military-industrial complex's influence on defense expenditures:

$$\text{Defense\_Expenditure} = \alpha_0 + \alpha_1\text{MIC} + \theta X + \varepsilon_1 \quad (2)$$

Estimating the effect of the military-industrial complex's influence on threat perceptions:

$$\text{Threat\_Perception} = \beta_0 + \beta_1\text{MIC} + \gamma_1 X + \varepsilon_2 \quad (3)$$

Estimating the effect of threat perceptions on defense expenditures while controlling for the military-industrial complex's influence:

$$\text{Defense\_Expenditure} = \alpha_0 + \alpha_1\text{MIC} + \alpha_2\text{Threat\_Perception} + \theta X + \varepsilon_3 \quad (4)$$

4.2 Variable Settings

The variable settings in this study are as follows:

4.2.1 Dependent variable

The level of defense expenditures for the sample countries, represented by the share of military expenditures in GDP. The military expenditure data is from the SIPRI Military Expenditure database.

4.2.2Explanatory variables

Objective military threat. Represented by the bilateral military power comparison with potential adversary countries (Russia). Flores [42] and Khaustova [43] pointed out that military power comparison is an important indicator for measuring the degree of threat when studying how nations respond to external threats. Syzov [44] emphasizes the importance of comparing military capabilities, such as personnel and equipment, to derive threat indices. When a

country perceives a significant military expenditure gap with its adversaries, it often leads to an increase in defense spending to address the perceived threat. This phenomenon is known as an arms race, where countries engage in a competitive cycle of military buildup to counter perceived threats [2]. Following Yeşilyurt and Elhorst [45]'s study, this study will use the ratio of the adversary country's military expenditures to the home country's military expenditures to measure the military threat faced by the country.

While military expenditure may not perfectly reflect military threat, as the efficiency of spending and actual military capabilities can vary, it remains a widely used and important indicator for comparing military power between countries [46-47]. In the absence of better quantifiable indicators, military expenditure comparison can still effectively reflect the relative military strength between countries to a certain extent. It is important to note that most European countries are members of military alliances such as NATO or the EU, and they may not fight alone. However, each country still needs to maintain a certain level of military power to fulfill alliance obligations and respond to potential security threats. The level of national defense spending reflects, to a certain degree, a country's emphasis on military power and its perception of external threats. Moreover, when facing common external threats (such as Russia), the comparison of military power among countries within NATO or the EU remains relevant, as it relates to burden-sharing and collective defense capabilities within the alliance. This study suggests that the relative comparison of military power with other countries can effectively reflect a country's sense of threat, especially in the context of European countries facing a common adversary. The raw data is from the SIPRI Military Expenditure Database.

Subjective threat perception. Represented by the change in bilateral trade growth, reflecting changes in threat perceptions. If a country's threat perception towards another country increases, it may take measures to restrict economic exchanges with that country [48]. In the context of this study, we focus on European countries' threat perceptions towards Russia, rather than towards other countries (such as Central African Republic, Myanmar, or Sudan) where sanctions may be implemented for reasons other than military threat perceptions. Against the backdrop of deteriorating bilateral relations, trade between European countries and Russia will typically decline or slow down. When a country adopts hostile policies towards another, it is often accompanied by reduced trade with that country. Restricting trade with the other party is a common means of exerting pressure during escalating conflicts between nations. On one hand, reducing trade helps limit the other party's access to strategic resources, weakening its national strength. On the other hand, the economic losses resulting from declining trade can serve as a deterrent and punishment for the other party. Therefore, changes in trade volumes often reflect a country's policy stance towards another country, from which its threat perceptions can be inferred [49-50].

To control for the impact of global price fluctuations on bilateral trade growth, we will include relevant global price indices for goods and services as control variables in the analysis. Additionally, we will consider using trade quantities instead of trade values as the measurement indicator to reduce the influence of price fluctuations. Furthermore, to address the potential impact of the COVID-19 pandemic on trade flows during the study period (2010-2022), we will control for the severity of the pandemic or the stringency of prevention measures as control variables in the analysis. The raw data is from the World Integrated Trade Solution (WITS) and the United Nations Commodity Trade Statistics Database (UN Comtrade Database).

Influence of the military-industrial complex. Represented by the share of arms exports, with a higher share indicating greater international influence of the country's military enterprises and thus greater domestic influence of the military-industrial complex [51-53]. A higher share of arms exports reflects the international competitiveness and influence of defense companies, which often stems from their domestic influence and close relationships with the government. Successful competition in the international market and obtaining a higher share of exports indicate that these companies possess advanced technologies, products, and marketing capabilities, which often benefit from their influence and close ties with the government at home.

Moreover, high levels of arms exports can bring more revenue and profits to defense companies, thereby enhancing their economic strength and political influence domestically. These companies can leverage their economic power to influence government decision-making and promote policies that favor their interests [54]. Arms exports often require government support and approval, as they involve sensitive national security issues. The ability of defense companies to achieve a high share of arms exports indicates their close cooperative relationships with the government, reflecting their domestic influence. Even for countries with relatively small domestic markets, defense companies can still maintain their production capabilities and technological advantages through exports, which contributes to their competitiveness and influence in the domestic market. The data is from the SIPRI Military Expenditure Database.

4.2.3 Control variables

GDP per capita. Used to control for the impact of economic development level on military expenditures. Data from the World Bank's WDI database.

Government fiscal revenue as a share of GDP. Used to control for the impact of government fiscal conditions on military expenditures. Data from the International Monetary Fund database.

NATO membership status. Considering NATO's requirement for member states to spend 2% of GDP on defence, a dummy variable is included to control for this, with 1 for NATO members and 0 for non-members.

Battle deaths by national armed forces. We will use the number of battle deaths suffered by national armed forces to control for the impact of armed conflict on military expenditures. This approach allows for a more nuanced measurement of conflict intensity and its potential influence on military spending. Data from the UCDP Battle-Related

4.2.4 Deaths Dataset

Global price indices for goods and services. To control for the impact of global price fluctuations on bilateral trade

growth, we will include relevant global price indices for goods and services as control variables in the analysis. Data from the World Bank's Global Economic Monitor (GEM) database.

COVID-19 pandemic severity or prevention measures. To address the potential impact of the COVID-19 pandemic on trade flows and other economic indicators during the study period (2010-2022), we will control for the severity of the pandemic or the stringency of prevention measures as control variables in the analysis. Data on COVID-19 cases and deaths will be obtained from the Johns Hopkins University Coronavirus Resource Center, while data on government response stringency will be obtained from the Oxford COVID-19 Government Response Tracker (OxCGRT).

Political stability. Political stability can influence a country's military expenditures and threat perceptions. To control for this factor, we will include the Political Stability and Absence of Violence/Terrorism index from the World Bank's Worldwide Governance Indicators (WGI) database as a control variable.

By incorporating these control variables, we aim to isolate the effects of the key explanatory variables (objective military threat, subjective threat perception, and influence of the military-industrial complex) on the dependent variable (military expenditures) while accounting for potential confounding factors. The inclusion of battle deaths by national armed forces, global price indices, COVID-19 pandemic severity or prevention measures, and political stability will help improve the robustness and reliability of our analysis.

4.3 Descriptive Statistical Analysis

Considering the research topic's specificity and data availability, this study selects 38 European countries as the research sample, covering different geopolitical, military-industrial strength, and strategic cultural backgrounds to enhance the explanatory power of the research conclusions. The sample time span is from 2010 to 2022, starting from a period before the Ukrainian crisis, to analyze the baseline levels of the military-industrial complex's influence, threat perceptions, and defense expenditures in European countries before the crisis. In 2014, the annexation of Crimea by Russia and the outbreak of the Ukrainian crisis marked the first major event of the Russia-Ukraine conflict, affecting threat perceptions in European countries. In 2022, the full-scale Russia-Ukraine conflict further escalated, impacting European countries' threat perceptions and defense expenditures. This time span can reflect the baseline conditions before the Russia-Ukraine conflict and capture the impacts of different stages of the conflict on European countries, facilitating a comprehensive examination of the moderating effect of the military-industrial complex's influence on threat perceptions and defense expenditures. Table 1 is the descriptive statistics of variables.

Table 1 Descriptive Statistics

variables	obs	mean	std	min	max
Defense_Expenditure	494	0.014	0.016	0.002	0.335
Threat	494	163.056	351.533	0.684	2241.938
Threat_Perception	494	-3.556	41.901	-100.000	141.794
MIC	494	3.371	20.330	0.000	253.444
GDP/per	494	285.546	245.686	20.329	1104.259
Fiscal_Revenue	494	0.375	0.069	0.201	0.569
NATO Member	494	0.688	0.464	0.000	1.000
Battle_Deaths	494	12.510	71.386	0.000	1200.000
Global_Price_Index	494	102.859	10.639	87.692	122.837
COVID_Severity	494	0.121	0.326	0.000	1.000
Political_Stability	494	0.601	0.426	-0.474	1.760

4.4 Empirical Results Analysis

Table 2 examines the moderating effect of the military-industrial complex's influence on threat perceptions. First, the impact of objective military threats on threat perceptions is not significant, indicating that objectively existing military threats do not necessarily translate into subjective threat perceptions at the national level. This finding is consistent with existing research conclusions that there are significant differences between objective threats and subjective threat perceptions [14,55]. Second, the influence of the military-industrial complex has a significant positive effect on threat perceptions, suggesting that the military-industrial complex can significantly increase a country's level of threat perception. This finding supports the core argument of the military-industrial complex theory, which posits that an alliance of arms merchants, the military, and members of Congress exaggerates external threats to pursue increased military spending [56-58]. Third, the interaction term between objective military threats and the influence of the military-industrial complex has a significant positive effect on threat perceptions, with a regression coefficient of 0.099, which is statistically significant at the 5% level. This means that the influence of the military-industrial complex significantly moderates the impact of objective military threats on subjective threat perceptions. Specifically, when the influence of the military-industrial complex is stronger, the impact of objective military threats on subjective threat perceptions is amplified. Conversely, when the influence of the military-industrial complex is weaker, the impact of objective military threats on subjective threat perceptions is diminished. This finding reveals the micro-mechanism by which the military-industrial complex influences defense policy formulation through moderating threat perceptions, and it also confirms Hypothesis 1 (H1).

Table 2 Moderating effect of MIC Influence on Threat Perception

	Dependent variable
	Threat Perception
Threat	0.110
	(0.119)
MIC	0.588***
	(0.092)
Threat*MIC	0.099**
	(0.045)
Control variables	Yes
Constant	0.146**
	(0.058)
Observations	494
R^2	0.497
Adjusted R^2	0.468

Note: *p<0.1; **p<0.05; ***p<0.01

Table 3 examines the effect of the military-industrial complex's influence on defense expenditures and the mediating effect of threat perceptions. In model (1), the influence of the military-industrial complex has a significant positive effect on defense expenditures, supporting the core argument of the military-industrial complex theory that the military-industrial complex drives increase in military spending by influencing defense policy formulation. In model (2), the influence of the military-industrial complex has a significant positive effect on threat perceptions, indicating that the military-industrial complex can increase a country's level of threat perception. This finding, together with the result in model (1), reveals two parallel mechanisms through which the military-industrial complex influences defense expenditures: First, the military-industrial complex directly affects defense policy formulation through lobbying, campaign contributions, etc. Second, the military-industrial complex indirectly increases decision-makers' threat perceptions through media propaganda, think tank reports, etc, thereby driving increases in military spending.

Table 3 MIC Influecne on Defense Expenditure and the Mediating Effect of Threat Perception

	Dependent variable		
	Defence Expenditure (1)	Threat Perception (2)	Defence Expenditure (3)
MIC	2.645***	0.743***	1.452***
	(0.287)	(0.087)	(0.235)
Threat Perception			1.608***
			(0.182)
Control variables	Yes	Yes	Yes
Constant	-0.634***	0.146**	-0.871***
	(0.181)	(0.058)	(0.160)
Observations	494	494	494
R^2	0.576	0.497	0.720
Adjusted R^2	0.551	0.468	0.703

Note: *p<0.1; **p<0.05; ***p<0.01
Bootstrap Statistics:
original bias std. error
1.196 0.005 0.246

In model (3), threat perception partially mediates the effect of the military-industrial complex's influence on defense expenditures. The regression coefficient of the military-industrial complex's influence decreases from 2.645 in model (1)

to 1.452 but remains statistically significant at the 1% level. Simultaneously, the regression coefficient of threat perception is 1.608, statistically significant at the 1% level. This indicates that threat perception is an important mediating variable through which the military-industrial complex's influence affects defense expenditures, confirming Hypothesis 2 (H2). Furthermore, in models (2) and (3), the regression coefficients β1 and α2 are both significant, and the regression coefficient α1 is smaller than in model (1), suggesting that threat perception partially mediates the effect of the military-industrial complex's influence on defense expenditures. Using the Bootstrap method to test the statistical significance of the mediating effect, the raw estimate of the mediating effect is 1.196, with a small bias (0.005) and a standard error of 0.246, further supporting the existence of the mediating effect. This indicates that the military-industrial complex not only directly drives increases in defense expenditures but also indirectly leads to higher defense budgets by influencing decision-makers' and the public's perceptions of external threats, revealing the complex landscape in which the military-industrial complex promotes military spending growth through dual pathways (direct and indirect influence).

In summary, the quantitative analysis results support Research Hypothesis 1 and Hypothesis 2: The influence of the military-industrial complex has a moderating effect on threat perceptions, and the military-industrial complex influences defence expenditures through shaping threat perceptions, with threat perceptions partially mediating the effect of the military-industrial complex's influence on defence expenditures.

4.5 Robustness Checks

When investigating the marginal effect of threat perceptions on the influence of the military-industrial complex, endogeneity is a significant challenge. The endogeneity problem primarily refers to the bidirectional causal relationship between the dependent variable (defence expenditures) and the core explanatory variable (threat perceptions), or that both are influenced by unobserved factors, leading to biased estimation results. To identify the unidirectional causal effect of threat perceptions on defence expenditures, the instrumental variable (IV) method can be employed. A qualified instrumental variable must satisfy two conditions: high correlation with the endogenous core explanatory variable (threat perceptions) and influence on the dependent variable (defence expenditures) entirely through the core explanatory variable, without any direct effect on the dependent variable. Therefore, this study selects the growth rate of neighboring countries' arms imports as the instrumental variable. According to the security dilemma theory, an increase in neighboring countries' arms imports may reflect an enhancement of their military capabilities, thereby heightening the home country's threat perceptions, but has less direct impact on the home country's defence expenditures.

Table 4 presents the empirical results of the IV-2SLS estimation. The Cragg-Donald Wald F statistic exceeds the Stock-Yogo 10% critical value, indicating no weak instrument problem. Compared to the previous analysis, the estimated coefficients of the core explanatory variables change slightly after 2SLS estimation using the instrumental variable, but remain statistically significant, suggesting robust results.

Table 4 Robustness Test

	Dependent variable			
	Threat Perception (1)	Defence Expenditure (2)	Threat Perception (3)	Defence Expenditure (4)
Threat	0.336***			
	(0.102)			
MIC	0.451***	0.682***	0.558***	0.542***
	(0.119)	(0.174)	(0.135)	(0.162)
Threat Perception				0.205*
				(0.116)
Threat*MIC	0.217**			
	(0.094)			
Control variables	Yes	Yes	Yes	Yes
Constant	1.356	1.178	1.297	1.051
	(0.912)	(1.252)	(0.970)	(1.173)
Observations	494	494	494	494
R^2	0.689	0.628	0.664	0.655
Adjusted R^2	0.672	0.611	0.648	0.637
Residual Std. Error	1.179	1.402	1.237	1.351

F Statistic	30.72***	38.54***	37.43***	30.61***

Note: *p<0.1; **p<0.05; ***p<0.01
Cragg-Donald Wald F: 23.67
Stock-Yogo 10%: 19.93

4.6 Heterogeneity Analysis

To enhance the explanatory power of the research conclusions, further heterogeneity analysis can be conducted by grouping the sample countries according to their geographic locations (Eastern Europe and Western Europe) and examining the differences in the moderating effect of the military-industrial complex on threat perceptions across different types of countries. The results reveal significant differences among different types of countries in the moderating effect of the military-industrial complex on threat perceptions. For Eastern European countries, the positive effects of objective military threats and the influence of the military-industrial complex on subjective threat perceptions are stronger. Additionally, the positive moderating effect of the military-industrial complex's influence on the relationship between objective military threats and subjective threat perceptions is also stronger in Eastern European countries. This suggests that the mechanism through which the military-industrial complex shapes threat perceptions differ across different types of countries. Eastern European countries have historically experienced more military conflicts and external threats, which may have granted their military-industrial complexes greater discursive power and influence in responding to objective threats.

It should be noted that, given the difficulties in obtaining cross-national data and the limitations of indicator measurements, the above research design may not be entirely immune to interference from econometric issues such as endogeneity. Furthermore, considering the complexity of European countries' military policies and interest bargaining, quantitative analysis alone may not fully capture the mechanisms through which the military-industrial complex exerts its influence. Therefore, this paper will further deepen the analysis of the process mechanisms underlying the military-industrial complex's influence through case studies.

5 CASE ANALYSIS

Considering the significant differences among European countries in terms of geopolitical pressures, military-industrial strength, and military cultural traditions, the research employs the Most Different Systems Design approach to select case countries, enhancing the explanatory power of the research conclusions. Specifically, using geographic region and the influence of military-industrial groups as criteria, two groups of European countries – France and Germany, Poland and the Czech Republic – are selected as comparative cases, with a focus on analyzing the operating logic and differential influence of the military-industrial complex against the backdrop of the Russia-Ukraine conflict.

5.1 France and Germany: The Historical and Cultural Underpinnings of the Military-Industrial Complex's Influence

France and Germany are the two major core countries of the European Union, exerting widespread and profound influence in the political, economic, and military spheres. The developmental trajectories and modes of operation of their military-industrial complexes largely reflect the common characteristics of major European powers' military-industrial interest groups. However, influenced by their historical cultural traditions and post-war development paths, the military-industrial complexes of France and Germany also exhibit distinct individual traits.

As a major military-industrial power in Europe, France boasts a long-standing military cultural tradition and a well-developed military-industrial system. The "military independence" strategy established during the de Gaulle era laid the political status and discursive foundation for France's military-industrial complex [59]. Although defence spending declined after the Cold War, military enterprises continued to exert influence over the national security agenda through deep involvement in defence policymaking. France's three major military-industrial giants – Dassault Group, Thales Group, and Naval Group – dominate various domains such as aviation, electronics, and shipbuilding. The French Aerospace Industries Association (GIFAS) is the most influential industry association, with over 400 member companies actively engaged in international exchanges and cooperation.

To illustrate the influence of the military-industrial complex on France's defence expenditure and threat perception, we can examine the trends in these variables. According to SIPRI data, France's military expenditure increased from €50.9 billion in 2010 to €52.7 billion in 2021, a 3.5% increase. During the same period, France's arms exports as a share of total exports increased from 1.2% to 2.1%, indicating the growing influence of the military-industrial complex. Moreover, France's bilateral trade growth with Russia slowed down significantly after the 2014 Crimea crisis, from an average annual growth rate of 5.2% during 2010-2013 to -0.8% during 2014-2021. This suggests that the military-industrial complex's influence on threat perception led to a deterioration in economic relations with Russia.

The French military-industrial complex is adept at leveraging geopolitical events to shape threat perceptions. Following the Ukrainian crisis, France's military-industrial complex swiftly called for enhancing Europe's "strategic autonomy" and reducing reliance on the United States in military affairs. For example, the French Senate emphasized that the Russia-Ukraine conflict highlighted Europe's vulnerabilities in areas such as the defence industry and energy supply, urging a substantial increase in the EU's common defence budget and the creation of a genuine "European Defence

Union". Within the NATO framework, France's military-industrial complex also actively promoted Russia's "aggression," providing public opinion support for strengthening NATO's eastern flank deployments. Benefiting from its strong political influence and discursive capabilities, France's military-industrial complex played a crucial role in shaping defence policymaking. In 2018, the Macron government issued the Military Programming Law, planning to increase the defence budget to €295 billion between 2019 and 2025, a 35% increase over the previous programming period [60]. This plan fully considered the interests of the military industry, such as significantly increasing investments in new-generation tanks, stealth fighters, and other equipment.

In contrast, the historical and cultural imprint of Germany's military-industrial complex is more complex. After World War II, guided by the constitutional spirit of "never again war," Germany long pursued a policy of military restraint, constraining the scale and political influence of its military industry. Germany's military-industrial complex is primarily composed of private military giants such as ThyssenKrupp and Rheinmetall GmbH, which occupy important positions in the global arms market. The German Security and Defence Industry Association (BDSV) is the main industry organization, actively lobbying on behalf of over 2,000 companies. However, influenced by historical memory and a strong tradition of civilian control, German military officers rarely take positions in military enterprises, resulting in a relatively distant civil-military relationship.

Germany's military expenditure remained relatively stable during 2010-2021, increasing slightly from €46.3 billion to €47.2 billion (SIPRI, 2022). Its arms exports as a share of total exports also remained low, fluctuating between 0.2% and 0.4%. This suggests that the influence of Germany's military-industrial complex on defence spending and arms exports is relatively limited. Moreover, Germany's bilateral trade with Russia continued to grow after the 2014 Crimea crisis, albeit at a slower pace, from an average annual growth rate of 8.3% during 2010-2013 to 2.1% during 2014-2021. This indicates that Germany's threat perception towards Russia was less influenced by the military-industrial complex compared to France.

Although Germany's military-industrial complex is massive in scale, its political influence is relatively limited, and its discursive strategies are more low-key. According to the German Federal Members of Parliament Act, members of parliament must publicly disclose any corporate positions they hold, which to some extent limits the lobbying space for military enterprises in parliament (Bundestag, 2022). German military think tanks, such as the Peace Research Institute Frankfurt (PRIF), tend to adopt more diverse policy stances, including critical voices against militarism and arms races. Although some German military enterprises called for increased defence budgets after the Russia-Ukraine conflict, they rarely emphasized the direct military threat from Russia. Instead, the German government tended to resolve the Ukrainian crisis through diplomatic means. For example, at the 2022 Munich Security Conference, Chancellor Scholz stated that Germany was willing to engage in dialogue with Russia on issues such as disarmament [61].

However, since the 21st century, Germany's military-industrial complex has gradually achieved a "normalization" of military production and exports by strengthening its industrial alignment with NATO. The full-scale outbreak of the Russia-Ukraine conflict has, to some extent, allowed Germany's military industry to seize the "turning point" opportunity, with the governing coalition and opposition parties pushing the government to enact a €100 billion special defence spending law and adjust its foreign arms sales policy, significantly relaxing arms export controls [61]. This means that after a difficult tearing of the "pacifist curtain," Germany's military-industrial complex is poised to regain its position as a key influencer of defence policy and military action.

By contrasting the performance of France and Germany's military-industrial complexes during the Russia-Ukraine conflict, the crucial role of military cultural traditions in shaping the influence of military-industrial interest groups becomes evident. Backed by the "de Gaulle legacy," France's military-industrial complex has been more proactive and assertive in responding to geopolitical upheavals. In contrast, influenced by the post-war "peace culture," Germany's military-industrial complex has faced a more arduous and circuitous path in shifting its policy preferences. However, the military-industrial interest groups in both countries have leveraged the conflict situation to reshape the national security agenda and ultimately pushed their governments to adopt policy adjustments favorable to the military industry. This demonstrates that under the threat of major military conflicts, the moderating effect of the military-industrial complex on the relationship between objective military threats and subjective threat perceptions is significantly enhanced, although the specific mode of influence differs due to differences in military cultural backgrounds.

5.2 Poland and the Czech Republic: The Geopolitical Drivers of Military-Industrial Complex Influence

As former socialist countries in Eastern Europe, Poland and the Czech Republic have both undergone arduous political and economic transitions after the Cold War, facing growing geopolitical pressures from Russia's resurgence in the region. The military-industrial complexes of both countries were generally affected by strategic downsizing and industrial restructuring during the transition period. However, with the rise of Russian security threats in recent years, military-industrial interest groups have regained discursive resources and played crucial roles in shaping defence policies.

As a major country in Eastern Europe in terms of population and economy, Poland possesses a relatively comprehensive military-industrial foundation, and its military-industrial interest groups wield significant influence over national security policies. Poland's military-industrial complex is primarily composed of state-owned military enterprises, with the Polish Armaments Group (PGZ) being the largest domestic military company, overseeing more than 70 subsidiaries operating in domains such as aviation, land equipment, and ammunition. Poland has also established the Polish

Armaments Industry Association (PSIA) as an industry association for military enterprises, actively engaged in policy lobbying and international cooperation.

To illustrate the influence of the military-industrial complex on Poland's defence expenditure and threat perception, we can examine the trends in these variables. According to SIPRI data, Poland's military expenditure increased from $8.7 billion in 2010 to $13.0 billion in 2021, a 49.4% increase. During the same period, Poland's arms exports as a share of total exports increased from 0.3% to 0.7%, indicating the growing influence of the military-industrial complex. Moreover, Poland's bilateral trade growth with Russia slowed down significantly after the 2014 Crimea crisis, from an average annual growth rate of 12.1% during 2010-2013 to -1.3% during 2014-2021. This suggests that the military-industrial complex's influence on threat perception led to a deterioration in economic relations with Russia.

Poland's military-industrial complex is adept at leveraging geopolitical events like the Russia-Ukraine conflict to exaggerate the security threats facing Poland. After the annexation of Crimea by Russia in 2014, Poland's military-industrial complex cited the Russian threat to push the government to significantly increase defence spending and launch a new round of military-industrial revitalization programs. By 2020, Poland's defence budget had reached $11.6 billion, accounting for 2.2% of GDP, exceeding NATO's requirement. After the full-scale outbreak of the Russia-Ukraine conflict in 2022, Poland's military-industrial complex further intensified threat propaganda targeting the government and public. For example, Polish Minister of National Defence Mariusz Błaszczak repeatedly stated publicly that Russia had amassed 100,000 troops on the Ukrainian border, posing a severe threat to Poland, and called for strengthening national defence development [62]. Polish military enterprises also seized the opportunity to promote the advanced capabilities and reliability of their military equipment, with PGZ highlighting on its official website that its missile systems, drones, and other products can effectively counter "threats from the East." The new round of weapons procurement announced by the Polish Ministry of National Defence, including 32 F-35 fighter jets, 250 M1 tanks, and more, with a total value exceeding $27 billion, involved many projects undertaken by domestic military enterprises [63].

In contrast to Poland, the Czech military industry is relatively smaller in scale, primarily focused on the production of light weapons and ammunition. VOP CZ and AERO Vodochody are two representative companies, producing armored vehicles and trainer aircraft, respectively. The Czech Defence and Security Industry Association (DSIA) is the main industry organization, with over 100 member companies.

The Czech Republic's military expenditure remained relatively stable during 2010-2021, increasing slightly from $2.2 billion to $3.4 billion. Its arms exports as a share of total exports also remained low, fluctuating between 0.2% and 0.4%. This suggests that the influence of the Czech military-industrial complex on defence spending and arms exports is relatively limited. Moreover, the Czech Republic's bilateral trade with Russia continued to grow after the 2014 Crimea crisis, albeit at a slower pace, from an average annual growth rate of 7.5% during 2010-2013 to 2.8% during 2014-2021. This indicates that the Czech Republic's threat perception towards Russia was less influenced by the military-industrial complex compared to Poland.

Nevertheless, Czech military enterprises have also been striving to expand their political influence. For instance, the Chairman of VOP CZ Group has publicly called on the government to increase defence investments and support the development of the domestic military industry [64]. Against the backdrop of the Russia-Ukraine conflict, Czech military enterprises and their political advocates have actively lobbied the government to increase defence budgets and military aid, citing the need to "defend Europe." Driven by the military-industrial interest groups, the Czech government has also begun to prioritize national defence development, emphasizing the necessity of strengthening defence capabilities. For example, in February 2022, Czech Minister of Defence Jana Černochová stated that Russia's troop build-up on the Ukrainian border posed a severe threat to European security, urging an increase in defence spending and accelerating the modernization of weapons systems [64]. The European Values Center for Security Policy, a Czech think tank, published a series of reports after the outbreak of the Russia-Ukraine war, analyzing the Russian military's operations in Ukraine and calling on the Czech government to aid Ukraine and intensify sanctions against Russia. The Czech government's new 2022-2026 Defence Development Strategy raises defence spending to 2% of GDP and initiates a series of weapons procurement projects, including 24 F-35 fighter jets and 200 infantry fighting vehicles [64].

By contrasting the performance of the military-industrial complexes in Poland and the Czech Republic during the Russia-Ukraine conflict, the crucial role of geopolitical pressures in shaping the policy preferences of military-industrial interest groups becomes evident. Military enterprises in both countries have capitalized on the "favorable" rise of the Russian threat to strengthen threat perception communication with their respective governments and publics, ultimately driving the expansion of defence spending and weapons procurement. Relatively speaking, Poland's military-industrial complex wields greater influence, attributable not only to its industrial scale advantages but also reflecting Poland's more assertive policy stance toward Russia. This underscores the moderating effect of the military-industrial complex on the relationship between objective military threats and subjective threat perceptions, largely stemming from the opportunistic changes in the geopolitical situation. Against the backdrop of increasing geopolitical pressures, the military-industrial complex's space for shaping threat perceptions has expanded, ultimately translating into tangible influence in promoting defence development and military action.

Through the comparative analysis of the military-industrial complexes in the France-Germany and Poland-Czech Republic cases, the theoretical framework and research hypotheses proposed earlier can be further enriched and refined. Overall, the cases of these four countries corroborate the basic logic of the military-industrial complex's role in reinforcing subjective threat perceptions and driving military force development amid geopolitical crises. Simultaneously, they reveal the distinctive characteristics of military-industrial interest groups' modes of influence under different contextual factors. Long-standing military cultural traditions and robust military-industrial foundations

have provided more favorable discursive resources and political mobilization conditions for the military-industrial complexes in countries like France and Poland. In contrast, the post-World War II "demilitarization" historical inertia and structural limitations of the military industry have rendered the military-industrial complexes in countries like Germany and the Czech Republic more passive and cautious in responding to geopolitical upheavals. However, it is noteworthy that the shocks of major military conflicts often become crucial opportunities for military-industrial interest groups to break free from existing path dependencies and reshape policy agendas. The case of Germany's military-industrial complex successfully pushing for a "sharp turn" in defence policy by forging alliances with political parties and think tanks after the outbreak of the Russia-Ukraine conflict serves as a typical illustration.

In summary, this part further refines the theoretical framework proposed earlier through comparative case studies, revealing the key role of military-industrial interest groups in leveraging major military conflicts, reinforcing subjective threat perceptions, and driving increases in defense spending. Although the modes of influence exerted by the military-industrial complex vary across countries, a common characteristic of its policy impact is the formation of interest coalitions with political actors such as parties, governments, and the public to secure primacy in defense resource allocation. In future analyses of the interaction between the military-industrial complex and national security agendas, it is essential to grasp the universal theoretical explanatory framework while fully considering the unique operational characteristics of military-industrial interest groups within specific historical contexts. Only then can we better elucidate the profound influence of the military-industrial complex as a political actor on a nation's military strategy amidst the complex and evolving geopolitical landscape.

6 CONCLUSION

Taking European countries as the research subject, this study systematically explores the theoretical mechanisms and empirical evidence regarding the influence of the military-industrial complex on defense expenditures. The research shows that military enterprises can influence policymakers' and the public's threat perceptions through various channels, thereby driving increases in defense budgets. Specifically, when the external security environment deteriorates, military-industrial interest groups often leverage their political influence and information advantages to exaggerate the security threats they face, amplify tense situations, and create a "hostile atmosphere" to secure more defense contracts and research projects, maximizing profits. This behavior distorts the nation's threat assessments, leading to inefficient allocation of defense resources. This study reveals a key micro-mechanism through which the military-industrial complex shapes threat perceptions, amplifying subjective security demands and thereby influencing defense policymaking. This finding breaks away from the traditional analytical path of military-industrial complex research, which focuses on the interaction between military enterprises and government decision-makers. It emphasizes the military-industrial complex's ability to manipulate information and influence public preferences, expanding our understanding of its operational logic.

COMPETING INTERESTS

The authors have no relevant financial or non-financial interests to disclose.

REFERENCES

[1] Robinson N. Videogames, persuasion and the war on terror: escaping or embedding the military—entertainment complex?. Political Studies, 2012, 60(3), 504-522.
[2] Nordhaus WD, Oneal JR, Russett B. The effects of the international security environment on national military expenditures: a multicountry study. International Organization, 2012, 66(3), 491-513.
[3] National Archives. President Dwight D. Eisenhower's Farewell Address, 1961.
[4] Rosen S. Testing the theory of the military-industrial complex. Lexington Books, 1973.
[5] Melman S. The Permanent War Economy: American Capitalism in Decline. Simon and Schuster, 1976.
[6] Giroux HA. The University in Chains: Confronting the Military-Industrial-Academic Complex. Routledge, 2007.
[7] Lai B. Slater D. Institutions of the offensive: domestic sources of dispute initiation in authoritarian regimes, 1950–1992. American Journal of Political Science, 2005, 50(1), 113-126.
[8] Whitten GD, Williams LK. Buttery Guns and Welfare Hawks: The Politics of Defence Spending in Advanced Industrial Democracies. American Journal of Political Science, 2010, 55(1), 117-134.
[9] Elveren AY, Hsu S. Military expenditures and profit rates: evidence from oecd countries. Metroeconomica, 2015, 67(3), 551-577.
[10] Eichenberg RC, Stoll RJ. Representing defense. Journal of Conflict Resolution, 2003, 47(4), 399-422.
[11] Koenig T, Troeger VE. Budgetary politics and veto players. Swiss Political Science Review, 2005, 11(4), 47-75.
[12] Cornish P, Edwards G. Beyond the eu/nato dichotomy: the beginnings of a european strategic culture. International Affairs, 2001, 77(3), 587-603.
[13] Fordham BO. The politics of threat perception and the use of force: a political economy model of u.s. uses of force, 1949-1994. International Studies Quarterly, 1998, 42(3), 567-590.
[14] Sinkkonen E, Elovainio M. Chinese perceptions of threats from the united states and japan. Political Psychology, 2019, 41(2), 265-282.

[15] Oliveira T, Martin MFO. Understanding e-business adoption across industries in european countries. Industrial Management & Data Systems, 2010, 110(9), 1337-1354.
[16] Vroege B. Strategic Autonomy in Military Production: The EDF and the Constitutional Limits to EU Defence-Industrial Spending Power. European Foreign Affairs Review, 2023, 28(4), 341-362.
[17] Smith KE, Fooks G, Gilmore A, Collin J, Weishaar H. Corporate coalitions and policy making in the european union: how and why british american tobacco promoted "better regulation". Journal of Health Politics, Policy and Law, 2015, 40(2), 325-372.
[18] MacLeavy J, Peoples C. Workfare–warfare: neoliberalism, "active" welfare and the new american way of war. Antipode, 2009, 41(5), 890-915.
[19] Feaver PD. Civil-military relations. Annual Review of Political Science, 1999, 2(1), 211-241.
[20] Izadi R. State security or exploitation: a theory of military involvement in the economy. Journal of Conflict Resolution, 2022, 66(4-5), 729-754.
[21] Yilmaz A. The missing piece of the puzzle: the emasya protocol and civil-military relations in turkey. Armed Forces & Society, 2022, 49(2), 470-488.
[22] Şengöz M. An Examination Of The National Security Paradigms Within The International Relations Discipline As On And Post-Cold War. Mecmua, 2022, 14, 182-198.
[23] Huddy L, Feldman S, Capelos T, et al. The consequences of terrorism: disentangling the effects of personal and national threat. Political Psychology, 2002, 23(3), 485-509.
[24] Ledbetter J. Unwarranted Influence: Dwight D. Eisenhower and the Military-Industrial Complex. Yale University Press, 2011.
[25] Knežević S, Obradović T, Milojević S. Managing the risk of corruption in the defense sector. Revizor, 2022, 25(99)
[26] Koroschupov VO. Some Aspects of European Defence Industry Development. World Economy and International Relations, 2022, 66(12), 87-107.
[27] Rufanges JC. The Arms Industry Lobby in Europe. American Behavioral Scientist, 2016, 60(3), 305-320.
[28] Mylonas Y. Discourses of counter-Islamic-threat mobilization in post 9/11 documentaries. Journal of Language and Politics, 2012, 11(3), 405-426.
[29] Aslam R. (2007). Measuring the peace dividend: evidence from developing economies. Defence and Peace Economics, 18(1), 39-52.
[30] Chen B, Li-ming Z. The determinants of china's defense expenditure before and after transition. Conflict Management and Peace Science, 2006, 23(3), 227-244.
[31] Konovalova M, Abuzov A. Geopolitical crises, the energy sector, and the financial capital market. E3S Web of Conferences, 2023, 381(01042), 1-7.
[32] Ghazanfar B, Khalid I, Qazi SM. Paradigm shifts in strategic culture of pakistan: an assessment of traditional versus non-traditional threat perceptions. Annals of Human and Social Sciences, 2022, 3(2).
[33] Gečienė-Janulionė I. The consequences of perceived (in)security and possible coping strategies of lithuanian people in the context of external military threats. Journal on Baltic Security, 2018, 4(1), 5-14.
[34] Bachleitner K. International memories in global politics: making the case for or against un intervention in libya and syria. Review of International Studies, 2023, 50(2), 271-288.
[35] Cohen D. Culture, social organization, and patterns of violence. Journal of Personality and Social Psychology, 1998, 75(2), 408-419.
[36] Liu D, Wang C, Fang C, Liu P. A study of project financing on the defense industry in systems thinking perspective. Journal of Applied Finance & Banking, 2021, 11(2), 131-149.
[37] Albareda A, Braun C. Organizing transmission belts: the effect of organizational design on interest group access to eu policy-making. JCMS: Journal of Common Market Studies, 2019, 57(3), 468-485.
[38] Shrestha YR, Ben-Menahem SM, Krogh GV. Organizational decision-making structures in the age of artificial intelligence. California Management Review, 2019, 61(4), 66-83.
[39] Hostert P, Kuemmerle T, Prishchepov AV, et al. Rapid land use change after socio-economic disturbances: the collapse of the soviet union versus chernobyl. Environmental Research Letters, 2011, 6(4), 045201.
[40] Moses IK. The reconstruction of nato in the post trump era. Journal of Advanced Research and Multidisciplinary Studies, 2021, 1(2), 10-17.
[41] Malizard J. Military expenditure and economic growth in the european union: evidence from sipri's extended dataset. The Economics of Peace and Security Journal, 2016, 11(2).
[42] Flores AQ. Alliances as contiguity in spatial models of military expenditures. Conflict Management and Peace Science, 2011, 28(4), 402-418.
[43] Khaustova VY, Kyzym M, Kostenko DM. Analyzing the International Assessments of the Military Power of the Armed Forces of Ukraine and Countries of the World. Business Inform, 2023, 541, 16-33.
[44] Syzov A, Koval O, Pakholchuk V. Military power and militarization of global space. Bulletin of Taras Shevchenko National University of Kyiv. Military-Special Sciences, 2022, 51(3), 49-55.
[45] Yeşilyurt ME, Elhorst JP. (). Impacts of neighboring countries on military expenditures: A dynamic spatial panel approach. Journal of Peace Research, 2017, 54(6), 777-790.
[46] Kollias C. Country survey military expenditure in Cyprus. Defence and Peace Economics, 2001, 12(6), 589-607.
[47] Aizenman J, Glick R. Military expenditure, threats, and growth. NBER Working Paper Series, 2003, 9618.

[48] Morgan TC, Bapat N, Kobayashi Y. Threat and imposition of economic sanctions 1945–2005: updating the TIES dataset. Conflict Management and Peace Science, 2014, 31(5), 1-18.
[49] Akoto W, Peterson TM, Thies CG. Trade composition and acquiescence to sanction threats. Political Research Quarterly, 2019, 73(3), 526-539.
[50] Peterson TM, Venteicher JF. Trade relationships and asymmetric crisis perception. Foreign Policy Analysis, 2012, 9(2), 223-239.
[51] Stavrianakis A. Introducing the special section on 'arms export controls during war and armed conflict'. Global Policy, 2023, 14(1), 107-111.
[52] Geyer M. Arms Exports: The Normality of a Scandalous Subject: A Comment. German Yearbook of Contemporary History, 2022, 6.
[53] Chopra A. China's Rise as an Arms Exporter: Implications for India. Claws Journal, 2020, 13(2), 81-96.
[54] Blum J. Arms production, national defense spending and arms trade: examining supply and demand. European Journal of Political Economy, 2019, 60, 101814.
[55] Haesebrouck T. Who follows whom? a coincidence analysis of military action, public opinion and threats. Journal of Peace Research, 2019, 56(6), 753-766.
[56] Moon C, Lee S. Military Spending and the Arms Race on the Korean Peninsula. Asian Perspective, 2009, 33(4).
[57] Collier P, Hoeffler A. Military expenditure - threats, aid, and arms races. Policy Research Working Papers, 2002.
[58] Pamp O, Thurner PW. Trading Arms and the Demand for Military Expenditures: Empirical Explorations Using New SIPRI-Data. Defence and Peace Economics, 2017, 28(4), 457-472.
[59] Belin J, et al. Defence industrial links between the EU and the US. Armament Industry European Research Group, 2017.
[60] Ministère des Armées. Loi de programmation militaire 2019-2025, 2018.
[61] Cabinet of Germany. Speech by Olaf Scholz, Chancellor of the Federal Republic of Germany and Member of the German Bundestag, at the Munich Security Conference, 2022.
[62] Website of the Republic of Poland. Meeting of NATO Defense Ministers, 2022.
[63] Terlikowski M. Defence Innovation: New Models and Procurement Implications. The Polish Case. Armament Industry European Research Group, 2022.
[64] Fajnor J. Government endorsed donation of military materiel from Czech defence industries. Ministry of Defence & Armed Forces of the Czech Republic, 2022.

Eurasia Journal of Science and Technology
ISSN: 2663-1016
DOI: 10.61784/ejst3013

RESEARCH ON INTEGRATED TEACHING OF ENGINEERING DRAWING COURSE INTO THE IDEOLOGICAL AND POLITICAL EDUCATION FROM THE PERSPECTIVE OF THREE COMPREHENSIVE EDUCATION

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Abstract: "Three comprehensive education" offers a roadmap for effectively improving the educational impact of fundamental professional courses. Engineering Drawing, a mandatory course for engineering students, plays a crucial role in shaping students' mindset and instilling professional ethics. Tailored to the objectives of talent development and course nature, this paper focuses on fostering virtues and imparting knowledge while honing professional skills in the context of teaching Engineering Drawing in China's application-oriented undergraduate colleges. By centering on the craftsman's spirit, it integrates ideological and political education cases to help students internalize correct values and attitudes, fostering a sense of national pride and professionalism, nurturing their spirit of innovation and craftsmanship. This approach leverages the holistic influence of professional courses, offering valuable insights for incorporating ideological and political education into engineering curricula.
Keywords: Engineering drawing; Ideological and political education; Three comprehensive education; Craftsman spirit

1 INTRODUCTION

Education is a cornerstone of the nation's vision. General Secretary Xi Jinping emphasized the importance of upholding the central principle of “fostering virtue through education” during the National Conference on Ideological and Political Work in Colleges and Universities. This entails integrating ideological and political work throughout all aspects of education and teaching in order to comprehensively educate individuals in all dimensions. By integrating various courses with ideological and political theory, a synergistic effect can be achieved. This lays the groundwork for advancing the ideological and political development of college courses in the new era and maximizing the educational impact of professional courses[1]. In May 2020, the Ministry of Education issued a document titled "Guiding Principles for the Ideological and Political Construction of the Curriculum of Institutions of Higher Learning," which clearly articulates that the fundamental issue of education lies in determining whom to train, how to train, and for whom to train. It emphasizes that the effectiveness of "fostering virtue through education" serves as the fundamental criterion for evaluating all activities within colleges and universities[2]. The document emphasizes the importance of integrating ideological and political principles into the curriculum in order to reinforce students' ideals and beliefs. This includes fostering patriotism, socialism, love for the people, and collectivism. The focus is on developing political awareness, national pride, cultural understanding, knowledge of the constitution, and moral values. The aim is to enhance the supply of ideological and political content within the curriculum and to incorporate education on socialism with Chinese characteristics, the Chinese dream, core socialist values, the rule of law, labor, mental health, and traditional Chinese culture. The overarching goal is to instill morality and cultivate well-rounded individuals. This approach aims to create a cohesive and comprehensive educational framework that aligns curriculum with ideological and political theory, with the fundamental task of education being the nurturing of virtue through teaching and practical application across all subjects[3]. Engineering science and technology play a crucial role in shaping the world, and the advancement of science and technology is a deliberate decision for humanity to address global challenges and attain sustainable development[4]. In engineering education, there should be a primary emphasis on enhancing students' understanding of engineering ethics, nurturing a dedication to excellence as skilled craftsmen, and inspiring a sense of duty to serve the nation through science and technology.

"Engineering Drawing" is a foundational course for engineering majors in China's application-oriented undergraduate colleges. It focuses on the interpretation, creation, and understanding of engineering drawings, playing a crucial role in preparing students for effective communication and enhancing their sustainable development skills in their future careers. The establishment of the School of Civil Engineering at Northwest Minzu University in November 2005 holds significant importance for the economic development and scientific and technological innovation in ethnic minority areas. The "Engineering Drawing" course is offered to three majors: Civil Engineering, Road, Bridge and River-Crossing Engineering, and Inorganic Non-metallic Materials Engineering. This paper uses the teaching practice of the "Engineering Drawing" course as an illustration, emphasizing the integration of knowledge delivery, value formation, and skill development. It places moral education at the core while aligning closely with the school's "three comprehensive education" reform requirements to implement a holistic approach to teaching and researching the engineering drawing course within the framework of curriculum ideology and politics.

2 CURRICULUM ANALYSIS AND TEACHING STATUS

2.1 Curriculum Analysis

"Engineering Drawing" is a fundamental course for science and engineering majors, playing a pivotal role in laying the groundwork for further professional studies and related engineering and technical work[5]. This course is aimed at freshmen, who are brimming with curiosity and enthusiasm as they embark on their university journey and embrace new disciplines. By seamlessly integrating ideological, political, and professional content, the course aims to foster a shift in students' mindset, instill a sense of responsibility, nurture familial and national pride, and elevate their social consciousness as they acquire professional knowledge and engineering skills. The ideological and political education within the course significantly aids students in transitioning to university life, fostering proper values and life perspectives, and swiftly comprehending the historical responsibilities that today's college students bear in this new era[6-8].

2.1 Current Status of Course Teaching

The "Engineering Drawing" course spans 48 class hours, comprising 16 class hours of theory and 32 class hours of practical work. The course covers fundamental concepts and skills related to drawing, engineering drawing, and CAD. Students often find the course challenging, particularly the section on three-view engineering drawing and professional drawing representation, which requires extensive practice. Given the limited class time and abundant content, it is a crucial and demanding task to effectively integrate ideological and moral education with course knowledge, ignite students' passion for learning, and instill ethical values while mastering professional and technical knowledge, ultimately achieving the training objectives for college students in the new era.

In the teaching process of this course, there is a significant emphasis on integrating ideological and political education. However, due to factors such as energy, interest, and cultural knowledge accumulation, most engineering teachers tend to prioritize technology and skills over ideological and political knowledge. As a result, the incorporation of ideological and political elements into the curriculum is not as effective as it could be. Some teachers focus excessively on the forms and requirements, creating a sense of rigidity and detachment from the professional courses. On the other hand, some teachers thoroughly consider ideological and political elements but struggle with integrating them cohesively due to a lack of overall logical relationship and resource integration. As a result, there is still room for improvement in realizing the goal of "three comprehensive education"[9-10].

3 MEASURES AND WAYS OF INTEGRATING IDEOLOGICAL AND POLITICAL EDUCATION IN ENGINEERING DRAWING COURSE

3.1 Teaching Principles of Engineering Drawing Course under the Ideological and Political Concept of Curriculum

The principles guiding the instruction of the engineering drawing course are founded on the fundamental principles and standards of ideological and political education[11]. They adhere to the underlying principles of education, teaching regulations, and course objectives. These principles showcase educators' grasp of the essential elements and teaching norms of engineering drawing courses. They form the basis for educators to devise instructional content, teaching sequences, teaching activities, and to employ effective teaching methodologies[12].

3.1.1 Student-centered principle

In consideration of the current situation of students, particularly the limited engineering knowledge of first-year students, the teaching content and structure are organized in a progressive manner, with teaching methods carefully selected. The instructional design prioritizes self-directed, hierarchical, and iterative learning for students. Teaching activities are designed to align with students' cognitive abilities, encouraging positive thinking and fostering their proactive engagement in learning.

3.1.2 Heuristic educational principle

The engineering drawing course integrates moral education content in a chapter-wise manner, aiming to stimulate students' enthusiasm through heuristic teaching activities. This approach encourages positive thinking, proactive practice, and the development of creative thinking skills. Throughout the teaching process, instructors utilize heuristic methods to address and resolve problems, incorporating practical problems, engineering examples, application instances, and knowledge structures. Emphasizing the essential unity of knowledge cultivation, thinking skills, ability development, and engineering literacy, the curriculum systematically integrates ideological and political education to subtly influence students' overall learning experience.

3.1.3 Intuitiveness principle

The incorporation of engineering geometric models in teaching is a defining feature of engineering drawing courses. By utilizing these models, students can gain a clear understanding of real-world objects, effectively bridging the gap between abstraction and concreteness. This approach allows students to develop a perceptual understanding of geometric shapes and engineering structures, fostering spatial awareness and improving their ability to observe and think spatially. Successful implementation of intuitive teaching rests on moderation and timeliness. It is crucial to strike the right balance and refrain from overusing teaching models to prevent students from becoming dependent on them. Timeliness entails allowing students space for independent thinking and empowering teachers to take on a guiding role. In addition to teaching models, instructors can use language and body language to encourage students to integrate observation, analysis, and imagination, resulting in more efficient and effective teaching.

3.1.4 Practical principle

The fundamental objective of the engineering drawing course is to foster students' capacity for innovative thinking and product design expression. This is achieved through the gradual imparting of knowledge and skills training. Following the completion of the instructional content, instructors can develop practical projects to aid students in furthering their comprehension, proficiency, and application of graphic theory. This approach enables students to cultivate a sense of accountability towards engineering and society, a practical innovative mindset, and foster their independent learning abilities.

3.2 Rebuilding Teaching Objectives of "Engineering Drawing" into Curriculum Ideological and Political Education

3.2.1 Teaching implementation methods

In alignment with the training plan and the ideological and political teaching objectives of the curriculum, we will refine the new curriculum teaching objectives. Focusing on these objectives, we will reconstruct the teaching content, activities, and evaluation to ensure a coherent alignment between our goals, content, teaching methods, and assessment. This will facilitate the seamless integration of ideological and political elements with professional knowledge within the teaching content. Our teaching approach will prioritize a student-centered, teacher-led philosophy, utilizing a blend of online and offline methods to effectively merge ideological and political education with professional teaching. Additionally, the course evaluation process will encompass assessment of ideological and political education, providing valuable feedback to enhance our teaching content and methods, ultimately serving the essential function of nurturing skilled professionals through education.

Table 1 Rebuilding Teaching objectives and ideological and political objectives of engineering drawing course

Target number	Target description	Target number	Target description
Course objective 1	Guide students to establish a correct world view, outlook on life and values, and strengthen the four self-confidences; Abide by engineering ethics and pay attention to the cultivation of students' craftsman spirit.	Ideological and political objective 1	Strengthen the road self-confidence theory self-confidence system self-confidence culture self-confidence with Chinese characteristics by integrating the ideological and political elements of the curriculum into the whole process of curriculum teaching.
Course objective 1	Master the basic knowledge of drawing in the professional aspect and the relevant requirements of drawing standards; Be able to use professional drawings to identify and judge the key links of complex engineering problems in professional fields; It can support the effective expression of key links in the design of engineering drawings through drawings.	Ideological and political objective 2	Combining Marxist viewpoints, viewpoints, and methods with the cultivation of scientific spirit in curriculum teaching can improve students' ability to correctly understand and solve problems.
Course objective 1	Understand the development history of drawing software (AutoCAD), understand the basic principles of drawing software, master the use of basic commands and drawing methods of drawing software, and be able to use these basic commands and drawing methods to draw engineering drawings.	Ideological and political objective 3	Pay attention to students' engineering ethics education, cultivate students' great country craftsman spirit of Excellence, and stimulate students' feelings of home and country and mission of serving the country through science and technology

3.2.2 Rebuilding teaching objectives

In December 2021, the Department of Higher Education of the Ministry of Education released a document titled "Comprehensive Promotion of Curriculum Ideological and Political Construction in Colleges and Universities." This document integrates the assessment of curriculum ideological and political construction effectiveness into the evaluation of undergraduate teaching, discipline, professional certification, and teaching achievement. As a result, it is essential for educators to integrate the effectiveness of curriculum ideological and political construction into the teaching objectives, leveraging the core values of curriculum ideology and politics and enhancing the educational function of the curriculum, as detailed in Table 1.

3.2.3 The teaching method of "integrated infiltration" of ideological and political education in engineering drawing course

The engineering drawing course incorporates ideological and political education through an integrated approach, with a strong emphasis on moral values. The main instructor is dedicated to promoting ethical behavior, learning, and teaching. The focus is on enhancing students' worldview, life outlook, and values by integrating moral education, aesthetic education, and subject knowledge into the course. The goal is to guide students in developing a proper understanding of their country, nationality, history, and culture, fostering well-rounded technical talents for the society's socialist development, as depicted in Table 2.

4 PRACTICAL TEACHING EFFECT OF INTEGRATING ENGINEERING DRAWING COURSE INTO IDEOLOGICAL AND POLITICAL EDUCATION

By integrating ideological and political courses with the teaching of engineering drawing and was implemented for a semester, students have shown increased initiative in learning "engineering drawing." They have demonstrated greater attention to detail in their homework exercises and drawing practice, leading to a significant reduction in drawing errors. Furthermore, during online courses, students have become more engaged in asking questions and have shown an improved attitude towards learning. According to students, the study of "engineering drawing" has cultivated a sense of patriotism and deepened their appreciation for the challenges and achievements in engineering made by the country. They expressed a commitment to maintaining a work ethic of excellence, rigor, and precision in their future endeavors, embracing a strong sense of responsibility and contributing to the modernization of the homeland.

Table 2 The correlation matrix of "integration infiltration" node and ideological education

Teaching content	Elements of ideological and political integration	Course teaching design	Expected results
Chapter 1: Basic knowledge and skills of engineering drawing	Awareness of obeying laws and regulations. How to be an excellent builder of Chinese dream.	Through asking questions, the necessity of drawing standards is introduced, and the basic knowledge and national standards of engineering drawing are introduced.	Strengthen the awareness of abiding by laws and regulations through the seriousness emphasized by the laws and regulations of "designing lifelong responsibility system"
Chapter 3: The expression method of engineering	Patriotic dedication, daring to tackle, courage to struggle, craftsman spirit	Through Liang Sicheng's Foguang Temple hand-drawn, the drawing method of section drawing is introduced in detail	By comparing the physical drawings, hand-drawn drawings and computer drawings of Foguang Temple, students can understand the craftsman spirit of the master and cultivate the craftsman spirit of rigorous, meticulous, serious and meticulous.
Chapter 5: Reinforced concrete structure drawing and steel structure drawing	The mastery of technical knowledge can realize the sense of historical mission and responsibility of serving the people's happy life for life and studying hard for the country's centennial rejuvenation	Introduce the learning, work, growth experience and advanced deeds of typical representatives of the construction industry, and invite students to talk about their feelings	Sow the seeds of love for the profession in the hearts of the students, develop a sense of professional pride in the school and major, and study hard for the goal of national development and construction and the people's better and happier life.
Chapter 6: Building engineering drawing	Introduce China's current advanced civil construction technology and infrastructure construction projects. Cultivate patriotic feelings as civil engineering professionals	Students make special presentations, and teachers comment	Combined with the deeds of "great country craftsmen", the spirit of patriotism is conveyed to students, and the work attitude of loving their own jobs, being down-to-earth, and striving for perfection is cultivated.

5 SUMMARY

Promoting foster virtue through education is a foundational mission of colleges and universities, and the primary duty of educators is to teach and guide individuals. Ideological and political education plays a vital role in nurturing morality and fostering citizens with patriotic values. Integrating ideological and political education into the curriculum should involve infusing specific courses with relevant content and utilizing distinctive ideological and political elements. By transcending traditional teaching methods and achieving a deep integration of knowledge transfer and ideological and political education, we can infuse ideological and political education throughout the entire teaching process. By emphasizing the "craftsman spirit," students can develop professional pride, recognize their sense of responsibility and mission, and significantly enhance their overall learning experience. This approach aims to enable students to achieve comprehensive development, cultivate high-quality professionals for society, and contribute to the great rejuvenation of the Chinese nation.

COMPETING INTERESTS

The authors have no relevant financial or non-financial interests to disclose.

FUNDING

This study was supported by the General Research Project on Education and Teaching Reform of Northwest Minzu University (No. 2023XJYBJG-47), the University Teachers Innovation Fund Project of the Department of Education of Gansu Province (No. 2023B-060), the Innovation and Entrepreneurship Education Teaching Reform Research Project of Northwest Minzu University (No. 2023XJCXCYJGXM26), the Undergraduate Talent Training and Improvement Project of Northwest Minzu University (No. 2022SYZX-01), the Fundamental Research Funds for the Central Universities (No. 31920220017), and Gansu Provincial Science and Technology Plan Project (No. 24JRZA054).

REFERENCES

[1] Yang Shengcai. Practical requirements of "three comprehensive education" in colleges and universities. HongQi WenGao, 2022, 09. http://www.qstheory.cn/dukan/hqwg/2022-09/13/c_1128998437.htm.
[2] Ministry of Education of the People's Republic of China. Guiding outline for the ideological and political construction of curriculum in colleges and universities. 2020, 06. http://www.moe.gov.cn/srcsite/A08/s7056/202006/t20200603_462437.html.
[3] Ouyang Sha et al. Unmasking the challenges in ideological and political education in China: A thematic review. Heliyon, 2024, 10(8) : e29176.
[4] Zhao Mingxia. Innovative Reform of Engineering Drawing Course Based on Design Project Drive. Journal of Physics: Conference Series, 2021, 1738(1): 012100. DOI: 10.1088/1742-6596/1738/1/012100.
[5] Zhu Wenbo, Cui Yuanyuan. Ideological and Political Exploration and Teaching Practice of Engineering Drawing Course. Advances in Educational Technology and Psychology, 2023, 7(15).
[6] Ni Linyan. Research on the core value of ideological and political construction leading the way of ideological and political education. Basic & Clinical Pharmacology & Toxicology, 2021, 128: 99-99. DOI: 10.1088/1742-6596/1738/1/012100.
[7] Gao Huiwen. Innovation and development of ideological and political education in colleges and universities in the network era. International Journal of Electrical Engineering & Education, 2023, 60(2): 489-499. DOI: 10.1177/00207209211013470.
[8] Ren Dongyi. Research on Teaching Reform of Engineering Drawing Course Based on Outcome-based Education. Atlantis Press SARL, 2024 : 144-149.
[9] Yang Shengluo, Yin Shuoxin, Zhu Wenbo. Instructional Design Integrated with Curriculum Politics for Engineering Drawing Based on a Network Teaching Platform. Curriculum and Teaching Methodology, 2023, 6(22).
[10] He Linqing, Tang Heye, Wang Fengzhou. The Exploration of Instruction Reform in Engineering Drawing Course Based on The Cultivation of Engineering Expression Ability. Advances in Higher Education, 2023, 7(17).
[11] Xia Haoyun. Research on Innovation of Ideological and Political Teaching Mode for Chemical Engineering Courses Based on Big Data Technology. Journal of Physics: Conference Series, 2021, 1852(3). DOI: 10.1088/1742-6596/1852/3/032001.
[12] Xue Junfang et al. Exploration and Practice of Innovative Teaching Mode of "Engineering Drawing" Course in Universities. Advances in Higher Education, 2022, 6(7).

Eurasia Journal of Science and Technology
ISSN: 2663-1016
DOI: 10.61784/ejst3014

RESEARCH ON THE DESIGN METHOD OF PYROTECHNIC FORMULAE

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Abstract: In this paper, in view of the continuous emergence of new experimental methods and the continuous improvement of old methods, how to reasonably select so many design methods has become a major problem for the formulation designers, the three commonly used formulation design optimization methods are briefly described, their advantages and disadvantages as well as their applications, especially in the formulation design of pyrotechnic drugs, and through a comprehensive analysis of various experimental methods, it is hoped to help Through the comprehensive analysis of various experimental methods, it is hoped that it will help the formulation designers to choose the formulation design methods reasonably.
Keywords: Formulation design; Optimisation methods; Pyrotechnics

1 INTRODUCTION

Formulation optimization is an important research content in the field of materials, In order to obtain formulations with excellent performance and meet the requirements of use, it is necessary to select raw materials reasonably and determine the dosage of various raw materials according to the performance requirements of the product and process conditions through testing, optimization and identification, For such a complex multi-objective formulation system, the design of the test method is particularly important, In recent years, the applied research on the optimal design of formulations is very active, new test methods continue to appear, the old methods continue to improve, in the face of so many design methods, how to reasonably choose has become a major problem for the formulation designer.
The formulation design of pyrotechnics is an important link in the research of pyrotechnics, and its quality and performance largely depend on the rationality of the formulation, Since in most of the formulation research, it is necessary to consider the influence law of two or more variable factors on the performance at the same time, with the help of the mathematical and statistical methods of statistical mathematics, it can change the many shortcomings of the traditional experimental design method such as the unreasonable distribution of test points, the number of tests, and the inability to reflect the interaction between factors, and so on, This paper addresses this issue in recent years, variety of experimental methods for comprehensive analysis, hoping to help formula designers to rationally select the formula design method, Currently the more commonly used methods are experimental methods, mathematical modelling and artificial intelligence.

2 EXPERIMENTAL METHODS

This method is a method of seeking the optimal material composition or optimal process conditions by systematically varying a variety of material and process parameters, This method is commonly used in the research and development of new materials, products and processes, and can also be applied to the improvement and optimization of existing materials and processes, Pyrotechnics can be selected as the optimal formula by experimentally testing the performance differences of different compositions or ratios of smoke generating agents, For example, the performance of a pyrotechnic agent can be evaluated by measuring parameters such as smoke density, colour and chemical composition, Among the many experimental methods, the orthogonal test method and the uniform design method are commonly used.

2.1 Orthogonal Test Method

Orthogonal experimental design is carried out through a set of carefully designed tables. Because the orthogonal table has the characteristics of orthogonality, balanced dispersion and neat comparability, so each No. l test has a strong representation, as long as the tests specified in the orthogonal table are done they can reflect the situation of the test in a more comprehensive way, and then the results of the orthogonal experimental design method of the formulation are analysed, one is an intuitive analysis, and the other is analysis of variance (ANOVA), Through the analysis of the test results (data),it is possible to determine the following: factors that have a significant impact on the indicators and factors that are not important to the indicators; the most favourable level combination for the indicators; the approximate range of changes in the indicators under the optimal level combination; the direction of further testing. The orthogonal test method has the characteristics of fewer tests and better representation of test points, and it can be used to analyse the results by both visual analysis and analysis of variance (ANOVA), and derive the significance of the factors and the optimal level combination [1]. The orthogonal experimental design has a good representativeness of the test sites.

orthogonal experimental design is more suitable for experimental arrangements with a low number of levels because the number of tests is at least the square of the number of test levels. It is widely used in the process off actor design and engineering optimisation in the fields of medicine, chemistry, manufacturing and engineering, Wang Wei [2] ,Guan hua [3], Ma Hongwei [4], Zou Jiaqi [5] et al. used orthogonal test method to carry out the formulation design of low detonation speed mixed explosives, infrared/mm wave resistant dual mode smoke generator, high precision boron deferred agent, and combustion type red phosphorus smoke generator, and the test results showed good performance, and the method has guiding significance for its formulation design.

2.2 Uniform Design Method

The uniform design method is a statistical analysis method used to determine the effect of multiple factors on an outcome. Unlike the orthogonal test method, the homogeneous design method does not require all factors to be arranged and combined, but rather the design is based on a measure of concordance, and the optimal "homogeneous design" point set is chosen to represent the range of values of the different factors, so as to obtain the optimal results with the minimum number of experiments.

The basic idea of the homogeneous design method is to divide the range of values of different factors into small intervals, each of which has representative value. When designing an experiment, a representative value is chosen from each sub-interval and these representative values are used to represent the experimental conditions. By optimising the choice of these representative values, the homogeneous design method allows the experimental results to be optimised in the minimum number of experiments.

The advantage of the homogeneous design method is that it does not require the full permutation and combination of each factor as in the orthogonal test method, thus saving experimental time and resources. It is also capable of handling non-linear multi-factor problems and is suitable for high dimensional experimental designs. Originally proposed by Japanese scholars Chou Itakura and Katsumi Tanaka in 1980, the homogeneous design method has been widely used in various fields, such as engineering, statistics, and computer science. Zhou Zunning [6], Min Jun [7], Zhou Mingshan [8], Wang Zongbei [9] et al. used the uniform design method against infrared hair and red phosphorus smoke agent and non-lethal weapon acoustic and optical bullet charge design.

3 MATHEMATICAL MODELLING

Mathematical modelling is a method of transforming practical problems into mathematical problems and solving them by building mathematical models to predict the performance of different formulations and select the optimal formulation. It is a comprehensive and widely applied technique that involves many fields such as mathematics, statistics and computer science. Usually, the problem is first clarified and the modelling objectives are determined; then data are collected processed and analysed; then an appropriate mathematical model is selected and solved; the next step is to validate the model and analyse the results; and finally, conclusions and recommendations are made on the basis of the results of the analysis. Lu Ming [10], Du Qianwei [11] by this method, several formulations of powdered ladder oil explosives, high power shock source pillars and gold containing mixed explosives were derived with reliable performance.

4 ARTIFICIAL INTELLIGENCE

Artificial Intelligence is the use of machine learning, neural networks and other artificial intelligence technologies, it can predict the best formulations for different materials and ingredients by analysing and modelling historical data, and verify them in practice. The advantages of artificial intelligence formulation design methods can quickly and efficiently generate formulas that meet the requirements, improving the efficiency of product development; and through a large amount of data analysis and learning, more accurate correlation laws and features can be found, importantly, human factors in the trial and error process are avoided, and the accuracy and stability of the formulation design is improved, At present, Al formulation design methods have been applied to many fields such as food, cosmetics, and medicine. In the formulation design of military pyrotechnic agents, Guo Haidong and Sun Yujie used support vector machine algorithms to predict the smoke density, colour and other performance indexes of different components of pyrotechnic agents. Xu Jilin [12] using CLPSO algorithm (Comprehensive Learning Particle Swarm Optimisation Algorithm), the optimal formulations were calculated and screened to prepare initial TATP and TNT explosive simulants.

5 CONCLUSION

Currently commonly used formulation design methods can be used to solve real-life problems, although they are different in nature, Their basic patterns, data requirements, speed and efficiency, and areas of application vary, In short, the various methods have their own advantages and disadvantages, the specific choice depends on the nature and needs of the research problem, according to the actual requirements of a reasonable choice, but also can be combined with each other to solve the problem, in order to reduce the consumption and greatly improve the efficiency of the work.

COMPETING INTERESTS

The authors have no relevant financial or non-financial interests to disclose.

REFERENCES

[1] Liu L. Xin Z. Xiang. Introduction to formulation optimisation design method. Rubber and Plastic Technology and Equipment, 2004: 8-12.
[2] Wang Wei, Shi Xiuwen. Optimisation of low detonation rate mixed explosives formulation. Blasting, 2003(1): 89-91.
[3] Guan H. Research on anti-infrared/millimetre wave dual-mode smoke generator technology. Nanjing University of Science and Technology, 2005.
[4] Ma Hongwei. Research on the performance of high-precision boron deferred drug. Anhui University of Technology, 2009.
[5] Zou Jiaqi. Research on the design and performance of combustion-type red phosphorus-type fuming agent. Nanjing University of Science and Technology, 2019.
[6] Zunning Zhou, Pan Gongmai, LI Yi, et al. Homogeneous design of infrared fuming agent formulations. Journal of Fire Explosives, 2003(2): 76-79.
[7] Min Jun. Study on the infrared extinction performance of red phosphorus fuming agent based on uniform design. Nanjing University of Science and Technology, 2008.
[8] Zhou Mingshan, Xu Ming, Shen Ruiji, et al. Application of uniform design method to the infrared extinction performance of red phosphorus fuming agent. Energy-Containing Materials, 2009, 17(3): 353-356.
[9] Wang Zubei. Non-lethal acoustic bullet charge design based on uniform design method. Chemical Engineering and Equipment, 2016(2): 153-155.
[10] Lu Ming, Hu Bingcheng, Du Yang. Research on the formulation of high power seismic source pillars. Journal of Fire Explosives, 2004(4): 6-9+32.
[11] Du Qianwei, He Bin, Wang Yuling, et al. Design of metal-containing explosive formulation based on genetic algorithm. Journal of Shandong University (Engineering Edition), 2009, 39(5): 149-152.
[12] Jilin Xu. Design and performance study of TATP and TNT analogue. Nanjing University of Science and Technology, 2021.

Eurasia Journal of Science and Technology
ISSN: 2663-1016
DOI: 10.61784/ejst3015

EXPLORING THE DEVELOPMENT OF CHINA-MONGOLIA INTERNATIONAL RAILWAY CONTAINER TRANSPORTATION COOPERATION

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Abstract: China-Mongolia international railway container transportation cooperation plays a crucial role in promoting the economic connectivity between the two countries, especially in the framework of the "Belt and Road" initiative and the "China-Mongolia-Russia Economic Corridor" which has made significant progress. This paper analyzes the current cooperation status and challenges of China-Mongolia railway container transport and discusses the potential direction of future cooperation. Although China and Mongolia have achieved certain results in infrastructure construction, logistics management and policy coordination, the problems of insufficient railway capacity, high cost of empty container transfer, differences in technical standards for cross-border railway switching, and extreme climate impact still exist. Future cooperation should focus on infrastructure connectivity, development of multimodal transport modes, railway capacity enhancement and promotion of green transportation. By deepening China-Mongolia-Russia trilateral cooperation, optimizing transport corridors and improving service levels, both sides will play a more important strategic role in the global supply chain.
Keywords: China-Mongolia Railway; Container transportation; Infrastructure connectivity; Multimodal transport

1 INTRODUCTION

Sino-Mongolian international railway container transportation cooperation plays a key role in promoting economic connectivity between the two countries. Mongolia, as an important hub in Asia and Europe, occupies an important position in China-Russia trade and the Belt and Road Initiative by virtue of its geographic location. Since its establishment in 1938, Mongolia's railway system has been the most important mode of transportation in the country, transporting more than 23 million tons of goods and 2.5 million passengers annually [1]. However, with the rapid economic and population growth, Mongolia's existing railway transportation capacity has made it difficult to meet the increasing demand. Therefore, how to improve the efficiency of railway transportation, especially the container transportation capacity, through Sino-Mongolian cooperation has become an urgent issue at present.

In recent years, China and Mongolia have made some progress in railway transportation, especially in the field of container transportation. Through the framework of the "Belt and Road" initiative and the "China-Mongolia-Russia Economic Corridor", China and Mongolia have continuously strengthened the interconnection of transportation infrastructure. The Joint Declaration of the Government of the People's Republic of China and the Government of Mongolia, signed in 2022, further defined the priorities of transportation and logistics cooperation, especially in containerized transit transport [2]. At the same time, Mongolia is actively opening up new sea routes, such as a new railway channel through Jinzhou Port in China, to further shorten the transportation distance and improve the efficiency of transportation [3].

Nevertheless, container transportation cooperation still faces challenges such as insufficient infrastructure, coordination of policies and regulations, and cross-border logistics management. The purpose of this paper is to analyze the current situation of China-Mongolia international railway container transport cooperation, the main problems and put forward the future development direction and cooperation proposals. By analyzing and summarizing the existing literature, this paper will provide strong theoretical support for how to deepen China-Mongolia railway container transport cooperation.

2 STATUS OF COOPERATION IN INTERNATIONAL RAILWAY CONTAINER TRANSPORTATION BETWEEN CHINA AND MONGOLIA

In recent years, China and Mongolia have made remarkable progress in international rail container transportation cooperation, especially under the "Belt and Road" Initiative and the China-Mongolia-Russia Economic Corridor, which have accelerated infrastructure construction and the docking of logistics networks. As China's land bridge to Europe, Mongolia's geographical advantage and strategic position have contributed to the increasingly important role of China-Mongolia international railway container transportation in regional trade and global supply chain.

First, the most important corridor for China-Mongolia rail container transportation is through the Erenhot-Zamyn-Uud

port. This corridor connects China's northern railway and Mongolia's mainline railway, and has become an important link for bilateral trade. In recent years, the freight volume of Erlianhot port has been rising, especially the growth in container transportation has been remarkable.2023 Erlianhot port Chinese-European trains 3,294, an increase of 30.8%; the total amount of import and export freight 4,079,000 tons, a year-on-year increase of 34.5%; entry and exit containers 375,000 boxes, a year-on-year increase of 39.4% [4]. The annual container transportation volume of Erlianhot railway port has been steadily increasing in recent years, showing the high dependence of both sides on this transportation line [5].2023 Sino-Mongolian trade showed a strong growth momentum, the total value of import and export of Erlianhot port was 42.31 billion yuan, an increase of 59.9% compared with the same period of last year, which is a new record high since this port has been in operation, and the value of Erlianhot port's trade with Mongolia accounted for about 30% of the national trade volume The trade volume of Erlianhot port to Mongolia accounts for about 30% of the country's trade volume, and 50% of Mongolia's means of production and 70% of its means of living are imported from the port [6]. In the same year, Mongolia's coal exports increased dramatically to 66.7 million tons, a significant increase of 110.5% over the previous year. According to Mongolian Customs, a staggering 99.5% of these exports, or 66.38 metric tons, were shipped to China [7].

In addition to the Erenhot-Zamyn-Uud port, the two sides are also working to develop new transportation corridors. Through Jinzhou Port, Mongolia has opened up a “multimodal” mode of transportation from sea to rail, which adds a new option to the China-Mongolia rail transportation network. Through Jinzhou Port, Mongolian goods can arrive at Chinese ports by sea and then be transported to many important nodes in Mongolia by rail [3]. This not only reduces the pressure on traditional transportation channels, but also provides a more flexible logistics path for economic and trade cooperation between the two countries.

The role of China Railway Express (CRE) in China-Mongolia railway container transportation cannot be ignored, and the regular operation of CRE has significantly improved the efficiency and speed of container transportation. For example, the transportation time from Erlianhot to Ulan Bator has been shortened from seven days in the past to about four days, which greatly reduces the transportation cost and improves the timeliness of logistics. The efficient operation of CRE not only improves the reliability of bilateral trade, but also reduces the overall cost of cross-border transportation, which makes import and export business between China and Mongolia smoother.

Nevertheless, China-Mongolia rail container transportation cooperation still faces some challenges. Compared with China, Mongolia's railway network is lagging behind in terms of infrastructure development, especially in terms of modern equipment and transportation efficiency. Most of the facilities of Mongolia's railway system were built in the mid-20th century, and some routes are often disrupted in winter due to extreme weather, for example, transportation from Zamyn-Uud to Ulaanbaatar was disrupted for two weeks in the winter of 2023 due to extremely cold weather. In addition, the emergence of transportation bottlenecks during winter and peak periods further limits transportation capacity and overall efficiency [1].

Taken together, the cooperation between China and Mongolia in the field of international railway container transportation has entered a new stage. Despite the remarkable progress, there is still a vast space for cooperation in the future. To further promote this cooperation, the two countries need to make more efforts in infrastructure investment and transportation corridor expansion. This will help to realize more efficient and mutually beneficial logistics cooperation, contributing to the economic growth and regional integration of the two countries.

3 CHALLENGES TO CHINA-MONGOLIA RAILWAY CONTAINER TRANSPORTATION

China-Mongolia railway container transportation has made remarkable progress in recent years, but still faces multiple challenges, mainly including lagging infrastructure construction, high transportation cost, imperfect international coordination mechanism, and unbalanced trade structure.

(1) Inadequate infrastructure and port capacity constraints

Lagging infrastructure and capacity bottlenecks are the main challenges. Mongolia's railway infrastructure is relatively outdated, making it difficult to adapt to the growing demand for transportation. Especially in the context of the rapid development of trade between China and Mongolia, the carrying capacity of Mongolia's railways is severely limited. This not only affects Mongolia's export capacity, but also limits Chinese companies' access to the Russian and European markets through Mongolia. Mongolia plans to upgrade its railway network on a large scale, but progress has been slow due to financial and technical problems. For example, parts of the railway and road infrastructure from the Bikhigtu border crossing to the interior of Mongolia still require large-scale investment and renovation. In addition, parts of the road in Mongolia, such as the road from the Bikhigatu border crossing to the city of Choibalsan, remain unpaved and gravel, and the transportation of containers by road faces safety and efficiency issues, which further slows down the timeliness of transportation.

(2) High transportation cost and empty container mobilization problem

Transportation cost is one of the major challenges faced by China-Mongolia railway container transportation, especially in the transfer of empty containers. There is an imbalance in the trade structure between China and Mongolia, with Mongolia importing relatively little, while its exports are mainly concentrated in minerals and livestock products, which leads to a large number of containers being empty on the return trip. The cost of transferring empty containers is passed on to the railway operator, reducing profitability and raising transportation costs. 2021 The backlog of containers due to the epidemic has exacerbated this problem, causing further increases in transportation costs, in particular container leasing fees and rising operating costs for logistics companies. This unbalanced transportation situation is one of the key

issues that China and Mongolia need to address together [8].

(3) Non-harmonization of transnational standards and the problem of changing tracks

Differences in technical standards for railway transportation between China and Mongolia are also one of the challenges. Mongolia uses wide rails, while China uses standard rails, which means that when containers are transported across borders, a rail change operation needs to be performed at the border. This process is complex and time-consuming, increasing transportation costs and time. At present, despite the corresponding measures taken by the two countries in terms of cooperation, the inconsistency of technical standards still poses a challenge to the efficiency of container transportation.

(4) Seasonal and climatic impacts

Extreme winter weather in Mongolia poses a serious challenge to China-Mongolia railway transportation. Every winter, temperatures in some parts of Mongolia drop to minus 30 degrees Celsius or lower, and this extremely low-temperature environment puts great pressure on railway lines and equipment. During the winter of 2022, a number of railway lines within Mongolia were disrupted due to the effects of snow and low temperatures, resulting in a nearly 20% decrease in rail transportation efficiency. Not only that, the harsh weather conditions also significantly increase the maintenance costs of the railway system, especially at border crossings, where extreme weather can lead to the closure of crossings and even multi-day transportation disruptions during outbreak prevention and control.

(5) Complexity of policy and cross-border coordination

Although China and Mongolia have signed a number of cooperation agreements on infrastructure development and logistics corridor construction, the inconsistency of policies at the concrete implementation level still poses a challenge to rail container transportation. Policy changes and regulatory uncertainties in Mongolia have often hindered the actual operation of Sino-Mongolian cooperation. 2022's new environmental transportation regulations in Mongolia have led to operational adjustments on some routes, a change that has directly impacted the normalization of Sino-Mongolian rail transportation plans. In addition, global economic uncertainty has exacerbated the problem, especially rising transportation costs and increased cross-border risks, making the two countries face a higher demand for policy coordination.

Overall, China-Mongolia railway container transportation cooperation faces not only the problem of insufficient infrastructure, but also the challenges of transportation costs, differences in technical standards and policy coordination. If both countries want to effectively solve these problems, they need to further promote the sustainable development of railway transportation by upgrading railway capacity, improving customs clearance efficiency and strengthening the consistency of technical standards.

4 FUTURE DIRECTION OF DEVELOPMENT AND SUGGESTIONS FOR COOPERATION

(1) Strengthening Infrastructure Connectivity

In the future, China-Mongolia railway container transportation cooperation should continue to deepen infrastructure connectivity, especially to promote the expansion and upgrading of railway network. According to Mongolia's Vision 2050, the construction of a railway from Choibalsan to Biqigtu is on the agenda [3]. The completion of this railway will significantly increase the container transportation capacity between China and Mongolia, laying a solid foundation for future regional economic and trade cooperation. In addition, we should continue to optimize the infrastructure of existing Sino-Mongolian ports, such as the Erlianhot and Zhoungha Dabqi ports. At the same time, strengthen cooperation with the node cities along the “Northeast Land and Sea New Corridor” to further improve logistics efficiency.

(2) Deepening the multimodal transportation model

Under the framework of the “Belt and Road” initiative, multimodal transportation has become an important development direction for cross-border logistics. By optimizing the seamless connection between railways, sea transport and land transport, the efficiency of cargo transportation between China and Mongolia can be improved. Future cooperation can reduce congestion at Tianjin Port and Erlianhot Port (Figure 1) by exploring a new corridor from Jinzhou Port to Zhungha Dabqi Border Crossing, where freight between China and Europe will transit through Mongolia. In addition, strengthening the application of information technology in multimodal transportation and building an intelligent logistics management platform will bring a more efficient and transparent operation mode for China-Mongolia logistics cooperation.

Figure 1 Erlianhot Port. Photo by Na Guo

(3) Enhancement of railway capacity and service level
In order to cope with the future growth of China-Mongolia railway transportation demand, it is particularly important to improve railway capacity and service level. By expanding the capacity of the railway and improving the frequency and speed of freight trains, the backlog of containers at the ports can be reduced. According to relevant studies, the capacity saturation problem faced by China-Mongolia railway transport can be optimized in the future through the introduction of advanced scheduling and transport management technologies to optimize the operational efficiency of trains. In addition, both sides of the cooperation should strengthen transportation safety measures, especially for the transportation environment of cross-border railways, to ensure the stability and safety of railway transportation.
(4) Promote the development of green transportation
In the context of economic development and environmental protection of China and Mongolia, future cooperation in railway container transportation should focus on green development. China and Mongolia can jointly promote clean energy trains to reduce the environmental pollution caused by traditional railway transportation. Introducing energy-saving and environmental protection technologies to reduce carbon emissions during container transportation will help enhance the green competitiveness of the two countries in the international market. In addition, promoting the greening of industrial parks and logistics parks along the routes will lay the foundation for the sustainable development of railway transportation between China and Mongolia.
(5) Deepening trilateral cooperation between China, Mongolia and Russia
As part of the China-Mongolia-Russia Economic Corridor, the future development of railway transportation between China and Mongolia should further strengthen cooperation among the three countries. Mongolia is located between China and Russia and plays an important role as a transit transportation hub. In the future, a closer cross-border transportation network can be formed by promoting policy coordination and infrastructure docking among China, Mongolia and Russia. For example, in the planning and construction of railway transportation routes, China and Mongolia should give full consideration to how to connect with Russia's railway network to promote more convenient transportation of goods between China and Europe [9].

5 CONCLUSION

The current status of cooperation in international railway container transportation between China and Mongolia shows that the two countries have made some progress in the construction of transportation infrastructure and logistics management. However, problems such as insufficient transportation capacity, low efficiency of ports and aging infrastructure still restrict the in-depth development of cooperation. In the future, the key to China-Mongolia railway container transport cooperation lies in optimizing infrastructure interconnection, promoting the development of multimodal transport, upgrading railway capacity and service level, and implementing green transport solutions. At the same time, by deepening the tripartite cooperation between China, Mongolia and Russia, China-Mongolia railway container transportation will be able to play a greater economic benefit and strategic significance under the framework of the “Belt and Road”.

COMPETING INTERESTS

The authors have no relevant financial or non-financial interests to disclose.

REFERENCE

[1] Gansukh, U., Ming, X., Ali, S. A. Analysis of the current situation of Mongolian railway and its future development. International Business Research, 2018, 11(5), 119-128.
[2] Government of the People's Republic of China & Government of Mongolia. Joint statement of the Governments of the People's Republic of China and Mongolia. People's Daily. 2022.
[3] Xu, X. B. Effect of the new China-Mongolia railway on Jinzhou Port. Port Engineering Technology, 2015, (06): 84-86. DOI: https://doi.org/10.16403/j.cnki.ggjs20150620.
[4] Li C.X. Erenhot Port handled 3,294 China-Europe freight trains in 2023. 2024. https://baijiahao.baidu.com/s?id=1787424939861539526&wfr=baike
[5] Chi, Y., Li, H., Gao, Y., et al. Research on the matching of the demand and capacity of China-Mongolia Erenhot Port trade and railway corridor transportation under the Belt and Road Initiative based on the Grey Correlation Method and countermeasures. In Proceedings of the 2nd International Conference on Mathematical Statistics and Economic Analysis, MSEA 2023, May 26–28, Nanjing, China, 2023.
[6] Li, A. P., Guo, N. The total import and export value of Erenhot Port reached 42.31 billion yuan in 2023, 2023. https://baijiahao.baidu.com/s?id=1788872140175391775&wfr=spider&for=pc
[7] CoalNewswire. Mongolia’s coal exports surge in 2023. The Coal Trader, 2023. https://thecoaltrader.com/mongolias-coal-exports-surge-in-2023/
[8] Li, R. F. An analysis of China-Mongolia transport and logistics cooperation: A case study of China-Mongolia container transit transportation. Northern Economy, 2023, (03): 33-35. DOI: https://doi.org/CNKI:SUN:BFJJ.0.2023-03-009.

[9] Jiang, Z. J. A study on the construction of the international cross-border transport corridor by China, Russia, and Mongolia. Northern Economy, 2019, (07): 31-38. DOI: https://doi.org/CNKI:SUN:BFJJ.0.2019-07-010.

Eurasia Journal of Science and Technology
ISSN: 2663-1016
DOI: 10.61784/ejst3016

AUTOMATIC GENERATION OF PILE-STRUT BRACING STRUCTURE OF EXCAVATION FROM BIM

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Abstract: BIM has been widely used in the construction engineering. At present, in the field of excavation engineering, BIM is mainly applied in the scheme presentation and construction simulation. There is little research work on structural analysis model of excavation generated by BIM. For pile-strut bracing structure of excavation, this paper proposes the IFC-based method of generation of structural analysis model from BIM. The model conversion program is developed in this paper. Through an excavation project in Shenzhen, the program application results verify the rationality of the model conversion method and the applicability of the model conversion program. This paper is helpful to the application of BIM in excavation design, and it is of great practical significance to improve the current design method of excavation.
Keywords: Excavation engineering; Pile-strut bracing structure; BIM (building information modeling); Structural analysis model; IFC (industry foundation classes)

1 INTRODUCTION

At present, BIM has been increasingly widely used in scheme presentation [1], construction simulation [2], project management [3], etc. In recent years, in the field of building engineering, research has been carried out in the use of BIM to generate structural analysis model. Deng et al [4] proposed a method for automatic generation of building structural models based on the IFC standard, and developed the IFC structural model server. Zhang et al [5] proposed a method for modeling three-dimensional solids based on AutoCAD graphics engine and converting solids to surface models, and verified the rationality of the method by Revit with examples. Huang et al [6] established a collaborative application platform for PKPM series software using IFC standard and developed an IFC interface to realize the conversion of PKPM software data into IFC format data. Wang et al [7] proposed an automatic model conversion method based on the building structural design information model and developed model conversion interface for structural analysis software ETABS. Wang et al [8] using AutoCAD as the development platform, developed IFC structural model conversion software based on structural analysis software 3D3S.
At this stage, in the field of excavation engineering, BIM is mainly used for scheme presentation and simulation of construction process [9]. There is little research work on the interface between BIM and the current design work method. For pile-strut bracing structure of excavation, this paper proposes the IFC-based method of generation of structural analysis model from BIM, and develop the model conversion program. The research in this paper contributes to the promotion and application of BIM in the design of excavation, and has some practical significance for improving current design methods of excavation.

2 BIM AND STRUCTURAL ANALYSIS MODEL OF EXCAVATION

2.1 BIM Model of Excavation

At present, there are many BIM software, such as ArchiCAD and Revit, which can build the BIM model of excavation. This paper adopts the more widely used software ArchiCAD to build the BIM model of excavation.

2.2 Structural Analysis Model of Excavation

At present, the three-dimensional analysis methods of pile-strut bracing structure of excavation are continuous medium finite element method and m-method. The former method studies the excavation including soil as a spatial system and comprehensively analyzes the internal force and deformation of the retaining structure. Although this method is theoretically mature, the calculation workload is large and the cost is high. The m-method [10] is based on the principle of m-method in the elastic foundation beam method. In the m-method, the soil body is considered as the soil spring unit in the excavation and the soil and water pressure outside the excavation, the retaining structure is regarded as a series of beams supported on a series of elastic bearings, the horizontal and vertical retaining system can generally be simulated by using the beam unit. The m-method is a practical method for design of excavation with clear concept and few calculation parameters. In this paper, the structural analysis model of m-method is used as the structural analysis model of excavation. Structural analysis model of m-method is shown in Figure 1.
Based on the BIM and structural analysis model of excavation, this paper studies the automatic generation of pile-strut bracing structure of excavation from BIM.

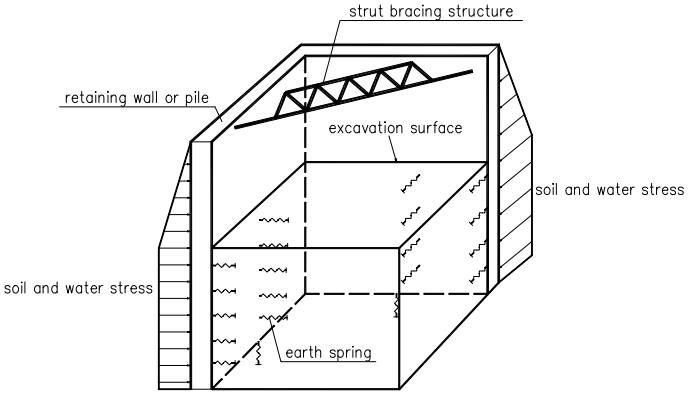

Figure 1 Structural Analysis Model of M-method

3 FORMAT FILE OF BIM AND STRUCTURAL ANALYSIS MODEL OF EXCAVATION

Selecting the appropriate format file of BIM and structural analysis model of excavation is the prerequisite and foundation for the automatic generation of pile-strut bracing structure of excavation from BIM.

3.1 Format File of BIM

In this paper, IFC standard file is used as the format file of BIM. IFC standard [11-14] is a widely accepted standard for product data exchange and sharing in the construction industry. More and more BIM software (e.g. ArchiCAD, Revit) are announcing their support for this standard. It provides a common building model and open data exchange standard to realize the collaboration between different design software in different disciplines and phases of the building life cycle.

The core technical content of IFC standard is divided into two parts: one is the description of engineering information, and the other is the transmission of engineering information. In this paper, IFC standard is briefly described as follows.

3.1.1 Description of engineering information.

The IFC standard uses the formal data specification language EXPRESS to describe construction engineering information. Language EXPRESS is fully defined in the STEP (Standard for the Exchange of Product Model Data) standard [15-16]. The information description of the IFC standard is divided into four levels, from bottom to top, namely resource level, core level, shared level and domain level, as shown in Figure 2. Each level contains several modules, and related engineering information is described in one module (e.g., geometry description module).

The resource layer defines the basic information of the model (e.g. materials, geometric topology, etc.); the core layer defines the overall framework of the information model (e.g. relationships between engineering objects, positions and geometry of engineering objects, etc.); the sharing layer defines the information exchanged across disciplines (e.g. walls, beams, columns, doors, windows, etc.); and the domain layer defines the information in their respective domains (e.g. piles, steel stranded wires, etc.).

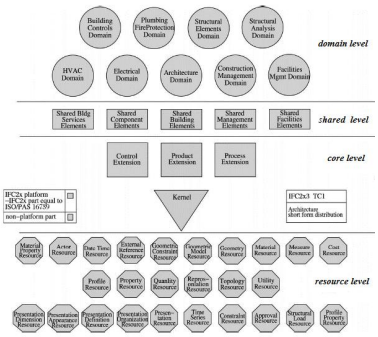

Figure 2 Information Description Hierarchy of IFC

3.1.2 Transmission of engineering information

The IFC standard exchanges information through a standard format file —a neutral file. A neutral file is a plain text format file that can be viewed and edited with an ordinary text editor. The file starts with "ISO-10103-21;" and ends with "END-ISO-10103-21;".There are two sections in the middle: a header section and a data section. The header segment starts with "HEADER;" and ends with "ENDSEC;" and contains information about the neutral file itself, such as the file description, the IFC standard version used, etc. The data segment starts with "DATA;" and ends with "END-ISO-10103-21;".The file data segment starts with "DATA;" and ends with "ENDSEC;", which contains the project information to be exchanged. The neutral file of a column is shown in Figure 3.

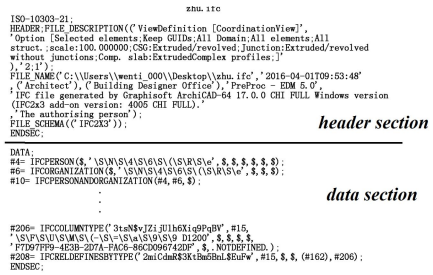

Figure 3 Neutral File of a Column

3.2 Format File of Structural Analysis Model of Excavation

The structural analysis model of m-method is generally built using the finite element software SAP2000. The s2k format file is one of a text format file generated by SAP2000. The s2k format file is clear, easy to read and write, and can be opened directly by word processing software such as writing pad and notepad. At the same time, the s2k format file is stable and not easy to make mistakes in the model conversion process. This paper adopts the s2k format file as the model conversion file.

The s2k format file uses several different TABLEs to completely describe the information of the model, such as point numbers and coordinates that use the TABLE: "JOINT COORDINATES". One part of the TABLE describes the software default information, such as SAP2000 software version, analysis standards, etc.; the other part of the TABLE describes the various definitions of the model information, such as the geometric properties of the model components, model constraints, loads, etc. Part of the typical s2k format file is shown in Figure 4.

Figure 4 A s2k File

4 PROGRAM DEVELOPMENT

On Visual Studio 2010 platform, using Visual C++ development tools, we developed our own model conversion program ArchiCAD To SAP2000 to realize automatic generation of pile-strut bracing structure of excavation from BIM.

4.1 General Agreements

To standardize the model conversion process and increase the applicability of the procedure, the following conventions are proposed for modeling with ArchiCAD.

(1) In order to facilitate the retaining structure, column, crown beam and strut of excavation can be connected normally in the vertical direction in SAP2000, the design elevation of crown beam and strut are the elevation at its neutral surface, while the top elevation of retaining structure and column are taken as the elevation at the neutral surface of the crown beam and support respectively.

(2) In order to facilitate the crown beam, waist beam and strut to be connected properly in the horizontal direction in SAP2000, the horizontal positioning axis of the above-mentioned components is their horizontal centerline.

(3) The model soil assumes uniform, horizontal distribution within layers, and each layer of soil is built using the ArchiCAD plate modeling module.

(4) To facilitate the addition of soil spring to the retaining structure, the IFC description attribute "TC-N" (N is a natural number) is added to the soil layer (slab) in ArchiCAD.

(5) In order to add soil and water pressure load to the retaining structure, the soil and water pressure surface of the retaining structure in ArchiCAD is established by deformation body modeling module, and the IFC description attribute "N" (N is a natural number) is added.

4.2 Program Development

The general flow chart of the program development is shown in Figure 5. The details are described as follows.
(1) Importing the IFC file generated by software ArchiCAD into the program to read and store the end point coordinates, section, material, constraints and load information of each structural unit of BIM model of excavation.
(2) Entering and storing the physical and mechanical properties of the soil in manual interactive input interface.
(3) The all information above is written to the file in s2k format.
(4) When the program ends, the s2k file is generated and saved.
(5) Importing the above s2k file into the software SAP2000 to generate the structural analysis model of excavation.

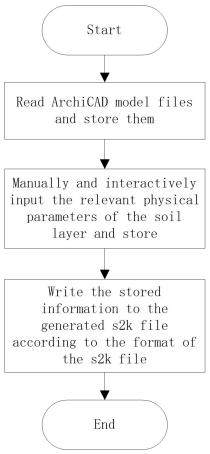

Figure 5 General Flow Chart of the Program

The conversion program ArchiCAD To SAP2000 including three modules:
(1) IFC file reading and parsing module: Load Ifc File;
(2) manual interaction module: Add Constraint and Add Load;
(3) s2k file generation module: Export s2k. The main interface of the program is shown in Figure 6.
(4)

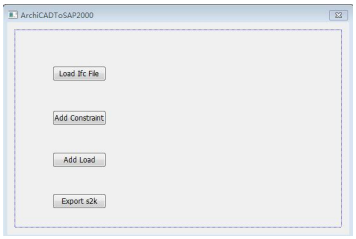

Figure 6 Main Interface Of The Program

5 PROJECT EXAMPLE

Taking the excavation project of ICBC building in Shenzhen as an example, the accuracy and applicability of the model conversion program developed in this paper are verified.

5.1 Project Summary

The excavation is located in the central area of Houhai, and the plan location is shown in Figure 7. The building has a four-story basement, the excavation depth is 20.0 m, and the perimeter of the excavation is 289.0 m. The site stratigraphy is relatively uniform, and the physical and mechanical property indexes of soil layer is shown in Table 1.

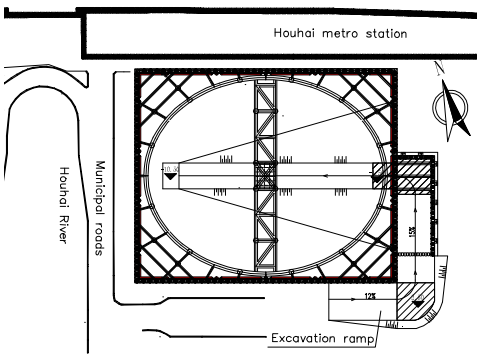

Figure 7 Plane Position of the Excavation

Table 1 Physical and Mechanical Property Indexes of Soil Layer

Soil	Layer thickness (m)	Severe (kN/m^3)	Cohesion (kPa)	Angle of internal friction (degree)	m value (kN/m^4)
Manual filling	8.4	18.9	12.0	16.0	4.72
Organic clay	2.5	17.1	14.0	5.0	1.40
Gravelly clayey soil	37.0	18.5	24.0	22.0	9.88

The excavation adopts the pile-strut bracing structure. The pile adopts the form of occluded piles, formed by 1.2m diameter reinforced concrete piles and 0.2m arrangement of the same diameter plain concrete piles occluding each other; the strut adopts three reinforced concrete ring strut. The typical support profile of the subway side of the excavation is shown in Figure 8.

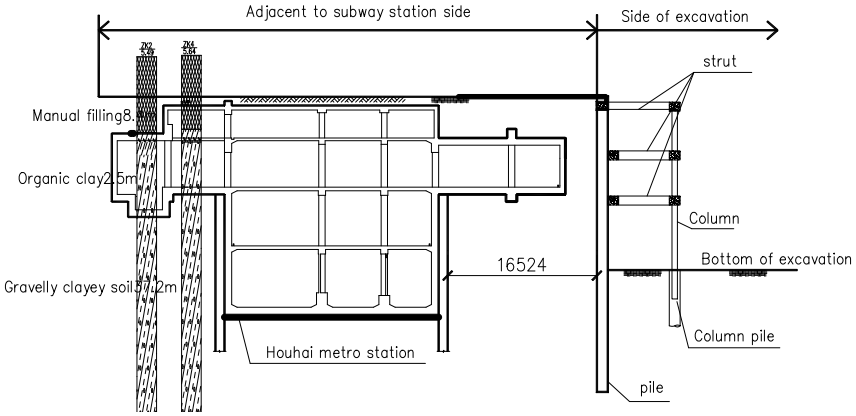

Figure 8 Retaining Profile of the Excavation at Metro Side (Unit: mm)

5.2 BIM Model of Excavation

The BIM model of the excavation built by ArchiCAD is shown in Figure 9. The BIM model of pile-strut bracing structure of excavation is shown in Figure 10. Because the plain concrete piles are not subjected to earth pressure, it can not be built in the model as shown in Figure 10.

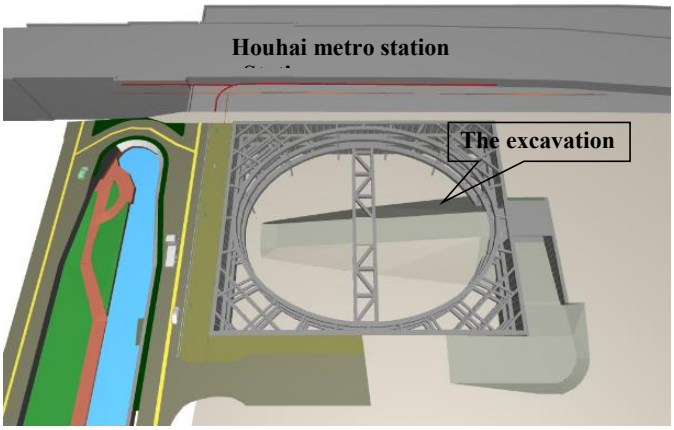

Figure 9 Building Information Model of the Excavation

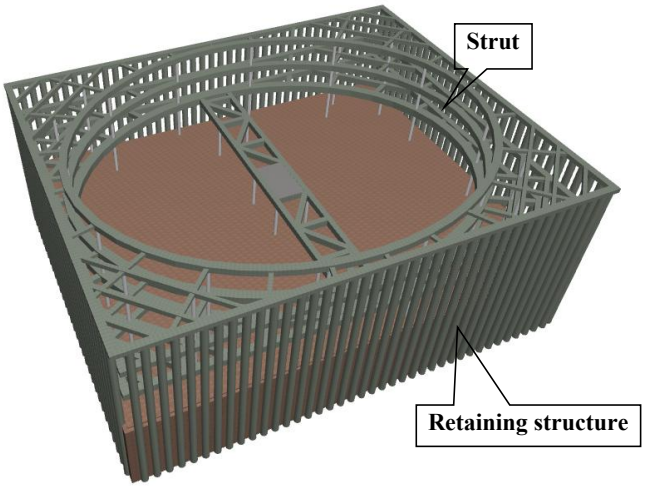

Figure 10 Building Information Model Of Pile-Strut Bracing Structure Of The Excavation

5.3 Generation of Pile-Strut Bracing Structure of Excavation in Sap2000

The BIM model of pile-strut bracing structure of excavation is exported in IFC format file. Start the program and click the IFC file reading and analysis module (Load IFC File), then select the above IFC file, and the program automatically analyzes and stores the end point coordinates, section, material, constraints and load information of each structural unit. Once the analysis is complete, click on the add constraint module of the manual interaction module, enter the soil spring stiffness value, and click on the add button when finished. Click on the add load module of the manual interaction module, enter the calculation parameters, and click on the compute button when finished. Finally, click on the SAP2000 s2k file generation module (Export s2k) to export the saved s2k file. The generated s2k file is imported into SAP2000 to automatically generate the structural analysis model of this excavation, as shown in Figure 11.

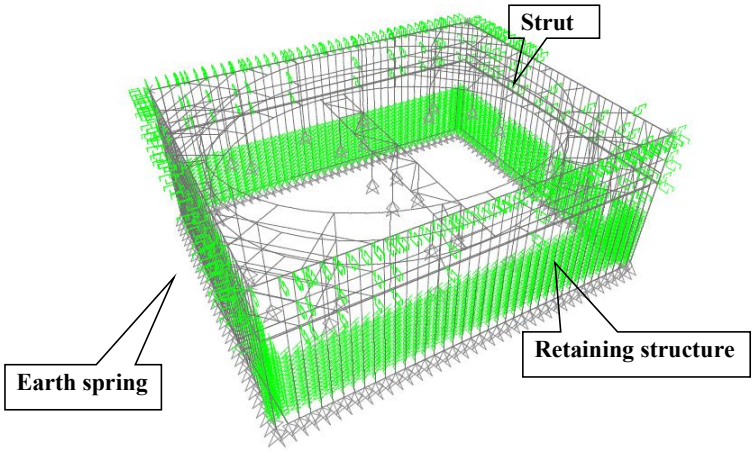

Figure 11 Structural Analysis Model Of The Excavation In Sap2000

6 CONCLUSIONS

This paper proposes the IFC-based method of generation of structural analysis model from BIM. The model conversion program is developed in this paper and verified by example through a excavation project. The conclusions and recommendations are as follows.

(1) The model conversion results of geometric position and section information of each member of retaining structure, column and internal retaining system in BIM are correct. The model conversion results of soil spring restraint in front of pile and soil and water pressure load outside the excavation are correct. The model conversion results verify the applicability of the model conversion program.

(2) The application results of example verify the rationality of the IFC-based method of generation of structural analysis model from BIM proposed in this paper.

(3) The model conversion method and development procedure are only applicable to the pile-strut bracing structure of excavation, and it is recommended to study the model conversion method for other forms bracing structure of excavation.

COMPETING INTERESTS

The authors have no relevant financial or non-financial interests to disclose.

REFERENCES

[1] Jun Su, Honghua Ye. The application of BIM-based design visualization in the German pavilion of EXPO 2010. Journal of Information Technology in Civil Engineering and Architecture, 2009, 1(1): 87-91.
[2] Bao-rong Jia. Exploration on the BIM technology application of Shanghai tower. CONSTRUCTION TECHNOLOGY, 2014, 43(app.): 254-258.
[3] Boya Ji, Zhenqiang Qi, Zhanyong Jin. BIM technology application in construction operation managemeng research—taking the Olympic village project as an example. Journal of Beijing University of Civil Engineering and Architecture, 2014, 30(1): 68-72.
[4] Xue-uan Deng, Zhiyong Zhang, Xila Liu. Automatic generation of structural model from IFC-based architectural model. China Civil Engineering Journal, 2007, 40(2): 6-12.
[5] Jianping Zhang, Yang Zhang, Xin Zhang. Methodolgy of 3D geometric modeling and model conversion of IFC-based BIM. Journal of Information Technology in Civil Engineering and Architecture ,2009, 1(1): 40-46.
[6] Jifeng Huang, Hanyi Zhang, Qi Nie. Application of BIM in structural design software. Journal of Information Technology in Civil Engineering and Architecture, 2011, 3(4): 58-62.
[7] Yong Wang, Jianping Zhang, Pengyi Wang et al. Model automatic transformation methods in architecture and structure designs. Journal of Architecture and Civil Engineering, 2012, 29(4): 53-58.
[8] Xuan Wang, Qie Hu, Huizhu Yang et al. Transformation technique of structural models based on industry foundation classes standard. JOURNAL OF TONGJI UNIVERSITY(NATURAL SCIENCE), 2014, 42(6): 836-843.
[9] Yiming Liu, Guonan Liu, Wentian Gu. Application of BIM visualization technology to foundation pit design. Railway Engineering, 2016, (6): 125-128.
[10] Jianhua Wang, Wei Fan, Weidong Wang et al. Application of 3D m-method in analysis of retaining structures of deep excavation. Chinese Journal of Geotechnical Engineering, 2006, 28(app.): 1332-1335.
[11] Tarandi V. Editorial: IFC-product models for AEC arena. ITcon, 2003, 8: 135-136.
[12] Kuining Qiu, Hanyi Zhang, Jing Wang et al. An introducetion of IFC by instances. Journal of Information Technology in Civil Engineering and Architecture, 2010, 2(1): 68-72.
[13] Hanyi Zhang, Kuining Qiu. An introducetion to shape representation and spatial structure of IFC by instances. Journal of Information Technology in Civil Engineering and Architecture, 2010, 2(2): 83-86.
[14] Lin Wang, Kuining Qiu. Analysis on IFC structure and data instances. Journal of Information Technology in Civil Engineering and Architecture, 2010, 2(4): 79-88.
[15] ISO10303-11. Industrial automation system and integration – Product data representation and exchange – Part 11: Description methods: The EXPRESS language reference manual.
[16] ISO10303-21. Industrial automation system and integration – Product data representation and exchange – Part 21: Implementation methods: Clear text encoding of the exchange structure.

Eurasia Journal of Science and Technology
ISSN: 2663-1016
DOI: 10.61784/ejst3017

OPN PROMOTES HYPERGLYCEMIA WITH CEREBRAL HEMORRHAGE AND NEUROINFLAMMATORY INJURY BY INDUCING MICROGLIA AND MACROPHAGE INFLAMMATION

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Abstract: Objective: To explore the role of OPN in hyperglycemia with cerebral hemorrhage and neuroinflammatory injury and its preliminary mechanism. Methods: BV2 cells/RAW264.7 macrophages were stimulated with 30 ng/mL OPN for 24 hours in advance, and then cultured with 33 mmol/L high glucose medium for 24 hours. The expression of IL-1 β and iNOS in RAW264.7 cells was detected by RT-PCR, and the expression of TNF - α in BV2 cells was detected by Western blotting. The hyperglycemia model of rats after ICH (ICH+HG) was constructed, and the intervention was performed with anti OPN monoclonal antibody (0.4 mg/kg) and intraperitoneal injection of endoplasmic reticulum stress inhibitor (TUDC) (200 mg/kg). After administration, the neurological function score and HE staining of intracerebral hemorrhage tissues were performed, and the secretion levels of iNOS and TNF - α in intracerebral hemorrhage tissues were detected by ELISA. Results: In RAW264.7 cells, high glucose culture significantly increased the expression levels of iNOS and IL-1 β. Compared with high glucose group, OPN further increased the expression levels of iNOS and IL-1 β. In BV2 cells, high glucose culture significantly increased the expression of IL-1 β and TNF - α. Compared with high glucose group, OPN further increased the expression of IL-1 β and TNF - α. The neurological function score of rats in ICH+HG group increased significantly. Compared with the model group, the neurological function scores of rats in OPN monoclonal antibody group and TUDC group decreased. Conclusion: OPN can promote hyperglycemia associated with cerebral hemorrhage by inducing microglia and macrophage inflammation.
Keywords: Bone bridging proteins; Hyperglycemia; Cerebral hemorrhage; Neuroinflammation

1 INTRODUCTION

Hyperglycemia combined with cerebral hemorrhage is a condition in which cerebral hemorrhage occurs on top of hyperglycemia. Hyperglycemia is a condition in which blood glucose levels are above the normal range and is common in people with diabetes[1]. Cerebral hemorrhage is bleeding caused by the rupture of a blood vessel in the brain, which seriously affects the function of the brain[2]. High blood sugar causes damage to the walls of blood vessels. High blood sugar damages the walls of blood vessels, making them fragile and prone to rupture, increasing the risk of brain hemorrhage. In addition, cerebral hemorrhage causes large amounts of blood to enter the brain tissue, resulting in increased pressure in the brain and damage to nerve cells and brain function. Hyperglycemia also exacerbates the inflammatory response to brain hemorrhage, increasing the degree and extent of brain damage[3, 4]. Hyperglycemia and cerebral hemorrhage are two separate diseases with some conflicting treatment strategies and drug choices. Hyperglycemia and cerebral hemorrhage are two separate disorders with some conflicting treatment strategies and drug choices; for example, cerebral hemorrhage requires inhibition of coagulation to control bleeding, whereas patients with hyperglycemia may require procoagulants to prevent vasculopathy. This therapeutic conflict confuses physicians in formulating a treatment plan[5, 6]. The molecular mechanism of cerebral hemorrhage in hyperglycemia is of great significance. Therefore, exploring the molecular mechanism of the pathogenesis of hyperglycemia combined with cerebral hemorrhage is of great significance for developing clinical treatment of hyperglycemia combined with cerebral hemorrhage.

Neuroinflammation has an important impact on hyperglycemia combined with cerebral hemorrhage. Neuroinflammatory response will further exacerbate the inflammatory response caused by cerebral hemorrhage, leading to a greater degree of cerebral injury and increased nerve cell death and dysfunction. At the same time, neuroinflammation activates inflammatory mediators, further damaging the cerebral blood vessel walls and increasing the risk of hemorrhage[7]. Microglia are the major immune cells in the central nervous system, and they play an important role in the neuroinflammatory process. When nerve tissue is damaged or infected, microglia are activated and release inflammatory mediators such as cytokines and chemokines. These inflammatory mediators can elicit an inflammatory response in the brain, attracting other immune cells to the lesion and exacerbating the degree of neuroinflammation[8, 9]. In addition, macrophages are activated and migrate to the site of injury, infection or inflammatory stimuli. In addition, when nerve tissue is stimulated by injury, infection or inflammation, macrophages are activated and migrate to the site of the lesion. Activated macrophages can release a variety of inflammatory

mediators, such as cytokines, chemokines, and oxygen free radicals. Excessive activation of macrophages may lead to uncontrolled inflammatory response and damage to neural tissues. Excessive release of inflammatory mediators may lead to exacerbation of inflammatory injury and even trigger cell death and tissue damage[10, 11]. The results of this study are summarized in the following table. Thus, microglia and macrophage hyperactivation may be involved in the pathogenesis of neuroinflammatory injury in hyperglycemia combined with cerebral hemorrhage.

Osteopontin (OPN) is a glycoprotein, which is widely distributed in the body, participates in a variety of biological processes, and has a variety of functions, including cell adhesion, migration, proliferation, inflammation regulation, etc[12]. OPN also plays an important role in the regulation of inflammation. It can regulate the activation and migration of immune cells and promote the occurrence and development of inflammatory reaction. In the process of inflammation, OPN can attract inflammatory cells into the focus and participate in the production and release of inflammatory mediators, thus affecting the degree and duration of inflammatory reaction[13, 14]. This study will explore the effect of OPN on the activation of microglia and macrophages to reveal its potential function in hyperglycemia with intracerebral hemorrhage, and provide a potential molecular target for clinical treatment of hyperglycemia with intracerebral hemorrhage.

2 MATERIALS AND METHODS

2.1 Cells and Treatment

Mouse microglia BV2 cell line (iCell-m011, Subekang) and mouse RAW264.7 macrophages (iCell-m047, Subekang) were purchased from Subekang. Both cells were cultured in complete DMEM medium (KGM12800, Keji Biology) under 5% CO2 and 37 ℃. In order to establish an in vitro high glucose induction model, BV2 cells/RAW264.7 macrophages were cultured for 24 hours in 33 mmol/L high glucose medium according to conventional methods. In order to explore the effect of OPN on the activity of high glucose stimulated BV2 cells/RAW264.7 macrophages, 30 ng/mL OPN was used to stimulate BV2 cells/RAW264.7 macrophages for 24 hours, and then 33 mmol/L high glucose medium was used to culture them for 24 hours according to the conventional method.

Real time fluorescent quantitative PCR (RT-PCR): use the pipette gun to suck out the cell culture medium in the culture dish, add Trizon lysate into the culture dish, blow with the pipette gun, make the adherent cell suspension fully contact with the lysate, collect all cell suspensions to extract RNA. The concentration and purity of RNA were determined by ultraviolet visible spectrophotometer (OD260/OD280). RNA was synthesized into cDNA through RNA reverse transcription kit. Fluorescent quantitative PCR was performed by using fluorescent PCR instrument. The reaction system is as follows: 2 × SYBR Green PCR Master Mix 10 μ l, cDNA 1 μ l, upstream primer 0.4 μ l, downstream primer 0.4 μ l RNase Free ddH20 8.2 μl。 The reaction steps are as follows: pre denaturation at 95 ℃ for 10 min; Denaturation 95 ℃, 10 s; Annealing at 58 ℃ for 30s; Elongation 72 ℃, 30s; 40 cycles. The sequence is shown in the following table. β - actin was used as the internal reference, and the relative expression of iNOS, IL-1 β, TNF - α was calculated according to the 2 -△△Ct method. See Table 1 for primer sequence.

Table 1 Primer Sequence in RTPCR Experiment

primer name	Primer sequence (5'-3')	Product length (bp)	Annealing temperature (℃)
β-actin F	AGGGAAATCGTGCGTGAC	192	58.0
β-actin R	CATACCCAAGAAGGAAGGCT		
iNOS F	GATGTGCTGCCTCTGGTCTTG	108	60.8
iNOS R	CCACTCGTACTTGGGATGCTC		
TNF-α F	CAGGCGGTGCCTATGTCTC	89	60.3
TNF-α R	CGATCACCCCGAAGTTCAGTAG		
IL-1β F	GAAATGCCACCTTTTGACAGTG	116	58.93
IL-1β R	TGGATGCTCTCATCAGGACAG		

2.2 Western Blot Detection

Discard the cell culture medium in the culture dish, add 100 μ L cell lysate into each hole, and place it on ice for 20 min. The pipette gun sucks into the marked EP pipe. Centrifuge with a 12000 r/min high-speed centrifuge for 10 min, discard the precipitation, take the supernatant and transfer it to a new EP tube (BCA determination), and store the total protein at - 80 ℃. Determine the protein concentration according to BCA kit, denature the protein, apply the sample to

SDS-PAGE for 1.5 h, and then apply 300 mA constant flow membrane for 1.5 h. Incubate the primary anti TNF - α (1:1000bs-0078r, Bios, China) with PVDF membrane, stay overnight at 4 ℃, incubate the secondary anti TNF - α with PVDF membrane at room temperature the next day for 2 hours, wash the membrane, wet the PVDF membrane with luminescent solution, and place it in the sample storage area of the ultra-high sensitivity chemiluminescence imaging system to run program development imaging.

Animal model construction and grouping administration: according to the method before John H Zhang's laboratory[15]. ICH+HG model was prepared by collagenase and 50% dextrose method. Collagenase VII was injected into the left cerebral basal ganglia (coordinates: 0.2 mm front, 6.0 mm belly, 3.0 mm outside), 0.075 units of collagenase was dissolved in 0.5 μ l normal saline, 0.25 μ l/min was injected for 2 min, and the rat ICH model was replicated. Three hours after ICH, 50% dextrose was injected intraperitoneally at the rate of 4g/kg to create a hyperglycemic model after ICH (ICH+HG). The ICH+HG model was made by intraperitoneal injection of 10 ml of 50% dextrose injection after establishing the collagenase basal ganglia injection method in rats with intracerebral hemorrhage. The anti OPN monoclonal antibody (0.4 mg/kg) and endoplasmic reticulum stress inhibitor (TUDC) (200 mg/kg) were respectively injected at the same location (unilateral) in the brain parenchyma 1 hour before and 1 hour after hemorrhage.

2.3 Neurological Scoring

Each rat was scored for neurological deficit according to the following scoring criteria: 0: no symptoms of neurological deficit; 1: inability to fully extend the left forelimb; 2: walking in a circle to the left; 3: walking in a tilt to the left; 4: inability to walk spontaneously, spasticity, lethargy, and loss of consciousness. A score of 1 to 3 during postoperative wakefulness indicated successful modeling; scores of 0 and 4 indicated modeling failure and were excluded.

2.4 HE Staining

The cerebral hemorrhage tissue was taken out and washed with running water for several hours 24 hours, 72 hours and 7 days after administration, and dehydrated with 70%, 80% and 90% ethanol solutions at all levels, mixed with pure alcohol and xylene for 15 minutes, and xylene I for 15 minutes and xylene II for 15 minutes (until transparent). Add the mixture of half xylene and half paraffin for 15min, and then add paraffin I and paraffin II for 50-60 minutes respectively. Paraffin embedding and sectioning. Bake paraffin slices, then dewax and hydrate them. Put the slices that have been put into distilled water into hematoxylin aqueous solution for staining for 3min, differentiate them with hydrochloric acid ethanol differentiation solution for 15s, slightly wash them with water, turn blue solution for 15s, wash them with running water, dye them with eosin for 3min, wash them with running water, dehydrate them, make them transparent, seal them, and conduct microscopic examination.

2.5 ELISA Detection

Collect the cerebral hemorrhage and surrounding tissues of rats, take the supernatant from the homogenate, measure the content of iNOS and TNF - α in the cerebral hemorrhage and surrounding tissues of rats by double antibody sandwich method, and refer to the instructions of corresponding ELISA kits for specific steps.

2.6 Statistical Method

SPSS 20.0 software was used for statistical analysis. All experiments were repeated three times, and the quantitative results were expressed as mean ± standard deviation (X ± S). Single factor analysis of variance was used for quantitative value comparison, and S-N-K method was used for pairwise comparison. $P<0.05$ was defined as significant difference.

3 RESULTS

Inflammatory release of RAW264.7 macrophages activated by OPN: In order to explore the effect of OPN on the activation of macrophages induced by high glucose, we used 30 ng/mL OPN to stimulate RAW264.7 macrophages for 24 hours in advance, and then cultured them in 33 mmol/L high glucose medium for 24 hours. Then RT-PCR was used to detect the expression levels of iNOS and IL-1 β in macrophages of each group. The results are shown in Figure 1. Compared with the Control group, In the model group, the expression levels of iNOS and IL-1 β increased significantly. There was a significant difference in the increase of iNOS expression, but there was no significant difference in the increase of IL-1 β expression. Compared with the Model group, the expression levels of iNOS and IL-1 β in the Model+OPN group were further improved, with significant differences.

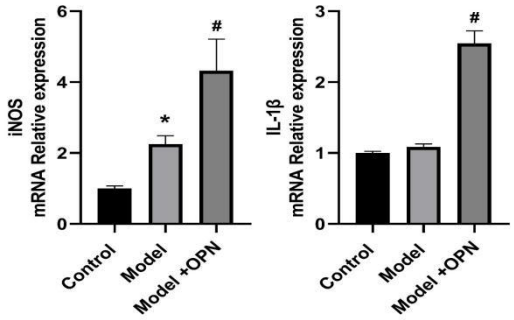

Figure 1 Inflammatory Release of RAW264.7 Macrophages Activated by OPN

Note: RT-PCR was used to detect the expression of iNOS and IL-1 β by RAW264.7 macrophages in each group (* p<0.05 vs. Control, # p<0.05 vs. Model).

3.1 Inflammatory Release of BV2 Cells Activated by OPN

In order to explore the effect of OPN on the activation of microglia induced by high glucose, we used 30 ng/mL OPN to stimulate BV2 cells for 24 hours in advance, and then used 33 mmol/L high glucose medium to culture for 24 hours, and then used RT-PCR to detect the expression levels of TNF - α and IL-1 β in BV2 cells in each group. The results are shown in Figure 2A, compared with the control group, In the model group, the expression levels of TNF - α and IL-1 β increased significantly. Compared with the Model group, the expression levels of TNF - α and IL-1 β in the Model+OPN group were further improved. There was a significant difference in the expression of IL-1 β, but there was no significant difference in the expression of TNF - α. In addition, Western blotting was used to detect the expression level of TNF - α in BV2 cells of each group. The results showed that (Fig. 2B), compared with the Control group, the protein expression level of TNF - α in the Model group increased slightly, with no significant difference. Compared with the Model group, the protein expression level of TNF - α in the Model+OPN group increased slightly, with no significant difference.

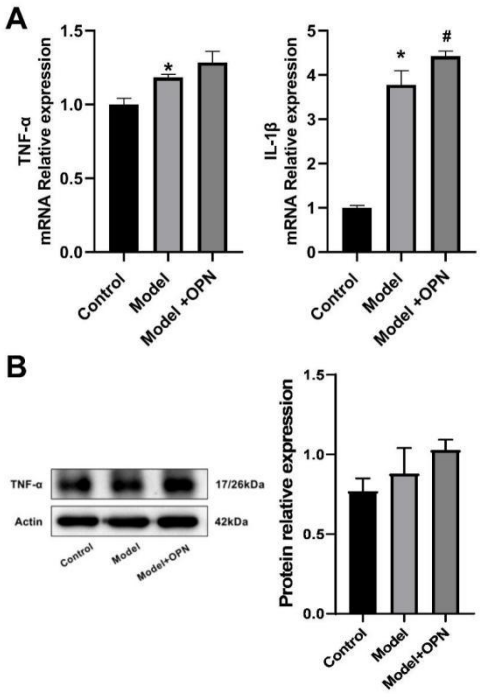

Figure 2 Inflammatory release of BV2 cells activated by OPN

Note: A. The expression levels of TNF - α and IL-1 β in BV2 cells were detected by RT-PCR; B. Western blotting was used to detect the expression level of TNF - α in BV2 cells of each group (* p<0.05 vs. Control, # p<0.05 vs. Model).

OPN inhibitor and endoplasmic reticulum stress inhibitor alleviated neuroinflammation in model rats: we further detected the secretion level of iNOS and TNF - α in intracerebral hemorrhage tissues, as shown in Figure 3. Compared with the control group, the secretion level of iNOS and TNF - α in intracerebral hemorrhage tissues of rats in ICH+HG group was significantly higher, with significant differences, compared with ICH+HG group, In ICH+HG+OPN and ICH+HG+TUDC groups, the secretion levels of iNOS and TNF - α in intracerebral hemorrhage tissues of rats decreased significantly, with significant differences.

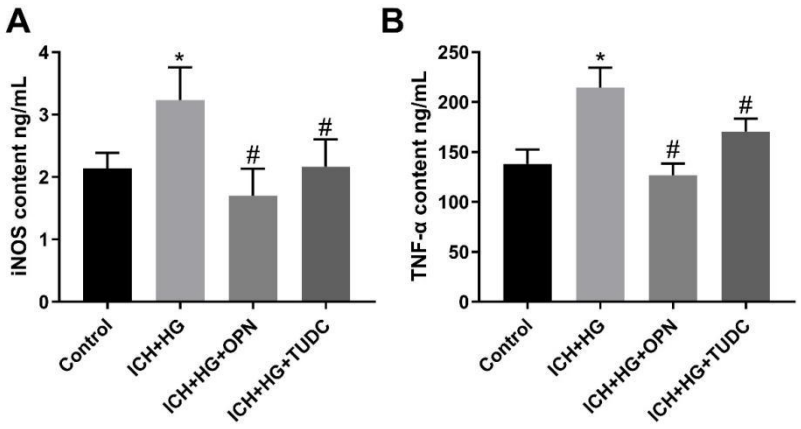

Figure 3 OPN inhibitor and endoplasmic reticulum stress inhibitor alleviate neuroinflammation in model rats
Note: ELISA was used to detect the secretion of iNOS and TNF - α in cerebral hemorrhage tissues of rats in each group (* $p<0.05$ vs. Control, # $p<0.05$ vs. ICH+HG).

4 DISCUSSION

Interleukin-1 beta and iNOS are important factors in the inflammatory activation of macrophages[16, 17]. IL-1 β is a cytokine that can regulate inflammatory response and immune response, and plays an important role in inflammatory activation of macrophages. When macrophages are infected by pathogens or other stimuli, they will release IL-1 β. IL-1 β can activate other immune cells, such as T cells and B cells, and promote the occurrence and development of inflammatory reaction[18]. It can also induce macrophages to produce other inflammatory mediators, such as TNF - α (tumor necrosis factor alpha) and IL-6 (interleukin-6), and enhance the intensity and duration of inflammatory response. In addition, IL-1 β can also affect biological processes such as cell adhesion, migration and proliferation by regulating gene expression[19]. INOS is an enzyme that can catalyze the production of nitric oxide (NO). In the inflammatory activation of macrophages, the expression of iNOS will be induced and increased[20]. Nitric oxide is an important inflammatory mediator that plays an important role in the inflammatory response. Nitric oxide is an important inflammatory mediator that plays an important role in the inflammatory response. It can inhibit the growth and replication of pathogens and enhance the bactericidal ability of macrophages. In addition, nitric oxide can affect biological processes such as cell proliferation, apoptosis and immune response by regulating cell signaling pathways[21]. This study found that high glucose stimulation significantly increased the expression of iNOS and IL-1 β in macrophages, which was close to the research results of Hua et al[22], indicating that high glucose stimulation significantly activated the inflammatory state of macrophages. In addition, the expression levels of iNOS and IL-1 β were further increased after the action of OPN, suggesting that OPN plays an important role in promoting the activation of macrophages induced by high glucose.

Microglia are specialized immune cells in the central nervous system, and they also play an important role in inflammatory activation[23]. When the central nervous system is injured, infected or other pathological stimuli, microglia will activate and release IL-1 β, which can promote the activation and proliferation of microglia. When inflammation occurs, microglia will be stimulated to release a large number of inflammatory mediators, and then continue to activate microglia, forming a positive feedback regulatory cycle[24]. In addition, IL-1 β can also regulate the activity of neurons, affect nerve conduction and neuroinflammatory reaction[25]. TNF - α is a proinflammatory cytokine produced by a variety of cells and plays an important role in regulating the immune and inflammatory response of the body[26]. TNF - α can activate the signal transduction pathway in the cell by binding to the TNF - α receptor on the surface of microglia, leading to the inflammatory response of the cell, including the release of proinflammatory cytokines, increased expression of cell adhesion molecules, and enhanced transcription of inflammation related genes. These reactions further trigger the infiltration and activation of inflammatory cells, forming the inflammatory cycle[27, 28]. This study found that high glucose stimulation significantly increased the expression of TNF - α and IL-1 β in mouse microglia, and the results were consistent with those reported by Zhang et al[29]. It showed that high glucose stimulation significantly activated the inflammatory state of mouse microglia. In addition, the expression levels of TNF - α and IL-1 β further increased after the action of OPN, suggesting that OPN plays an important role in promoting the activation of microglia induced by high glucose.

This study found that OPN inhibitors and ER stress inhibitors can significantly improve the brain tissue pathology of rats with hyperglycemia and intracerebral hemorrhage. With the partial improvement of neural function and the reduction of brain tissue inflammation, it suggests that the effect of OPN inhibitors may be similar to ER stress inhibitors, but this needs further experimental verification[30].

This study preliminarily revealed the potential role of OPN in the pathogenesis of hyperglycemia with cerebral hemorrhage, and found that its role may be related to the activation of inflammatory function of macrophages and microglia. However, this study has some shortcomings. First, in vitro studies found that OPN has a significant role in

promoting the inflammatory activation of macrophages and microglia, However, the results in vitro were not verified by means of immunofluorescence in vivo. In addition, whether the improvement effect of OPN inhibitor on hyperglycemia rats with intracerebral hemorrhage is related to the inhibition of endoplasmic reticulum stress, it is necessary to jointly give OPN inhibitor and endoplasmic reticulum stress agonist to model rats to observe the pathological changes of rats. In future experiments, we will further explore the internal molecular mechanism of OPN regulating inflammatory activation of macrophages and microglia, and better understand its role in the pathogenesis of hyperglycemia combined with cerebral hemorrhage.

To sum up, this study found that OPN may promote hyperglycemia with neuroinflammatory damage after intracerebral hemorrhage by inducing microglia and macrophage inflammation.

COMPETING INTERESTS

The authors have no relevant financial or non-financial interests to disclose.

FUNDING

The project was supported by Research Cooperation Project of Guizhou Provincial Department of Science and Technology, [2020]1Y426; Doctoral Research Initiation Fund of Zunyi Medical University Affiliated Hospital, (2019)02.

REFERENCES

[1] Wang Y, Li K, Liu Z, et al. Ethyl Pyruvate Alleviating Inflammatory Response after Diabetic Cerebral Hemorrhage. Curr Neurovasc Res, 2022, 19(2): 196-202.
[2] Diener HC, Hankey GJ. Primary and Secondary Prevention of Ischemic Stroke and Cerebral Hemorrhage: JACC Focus Seminar. J Am Coll Cardiol, 2020, 75(15): 1804-1818.
[3] Chen S, Wan Y, Guo H, et al. Diabetic and stress-induced hyperglycemia in spontaneous intracerebral hemorrhage: A multicenter prospective cohort (CHEERY) study. CNS Neurosci Ther, 2023, 29(4): 979-987.
[4] Sun S, Pan Y, Zhao X, Liu L, Li H, He Y, et al. Prognostic Value of Admission Blood Glucose in Diabetic and Non-diabetic Patients with Intracerebral Hemorrhage. Sci Rep, 2016, 6: 32342.
[5] Chang JJ, Khorchid Y, Kerro A, et al. Sulfonylurea drug pretreatment and functional outcome in diabetic patients with acute intracerebral hemorrhage. J Neurol Sci, 2017, 381: 182-187.
[6] Yang S, Liu Y, Wang S, et al. Association between high serum blood glucose lymphocyte ratio and all-cause mortality in non-traumatic cerebral hemorrhage: a retrospective analysis of the MIMIC-IV database. Front Endocrinol (Lausanne), 2023, 14: 1290176.
[7] Ding H, Jia Y, Lv H, et al. Extracellular vesicles derived from bone marrow mesenchymal stem cells alleviate neuroinflammation after diabetic intracerebral hemorrhage via the miR-183-5p/PDCD4/NLRP3 pathway. J Endocrinol Invest, 2021, 44(12): 2685-2698.
[8] Subhramanyam C S, Wang C, Hu Q, Dheen S T Microglia-mediated neuroinflammation in neurodegenerative diseases. Semin Cell Dev Biol, 2019, 94: 112-120.
[9] Voet S, Prinz M, Van Loo G. Microglia in Central Nervous System Inflammation and Multiple Sclerosis Pathology. Trends Mol Med, 2019, 25(2): 112-123.
[10] De Vlaminck K, Van Hove H, Kancheva D, et al. Differential plasticity and fate of brain-resident and recruited macrophages during the onset and resolution of neuroinflammation. Immunity, 2022, 55(11): 2085-2102 e2089.
[11] Hegdekar N, Sarkar C, Bustos S, et al. Inhibition of autophagy in microglia and macrophages exacerbates innate immune responses and worsens brain injury outcomes. Autophagy 2023, 19(7): 2026-2044.
[12] Icer MA, Gezmen-Karadag M. The multiple functions and mechanisms of osteopontin. Clin Biochem, 2018, 59: 17-24.
[13] Fortis S, Khadaroo RG, Haitsma JJ, et al. Osteopontin is associated with inflammation and mortality in a mouse model of polymicrobial sepsis. Acta Anaesthesiol Scand, 2015, 59(2): 170-175.
[14] Fu H, Liu X, Shi L, et al. Regulatory roles of Osteopontin in lung epithelial inflammation and epithelial-telocyte interaction. Clin Transl Med, 2023, 13(8): e1381.
[15] Manaenko A, Yang P, Nowrangi D, et al. Inhibition of stress fiber formation preserves blood-brain barrier after intracerebral hemorrhage in mice. J Cereb Blood Flow Metab, 2018, 38(1): 87-102.
[16] Kashfi K, Kannikal J, Nath N. Macrophage Reprogramming and Cancer Therapeutics: Role of iNOS-Derived NO. Cells, 2021, 10(11).
[17] Zhu L, Zhao Q, Yang T, et al. Cellular metabolism and macrophage functional polarization. Int Rev Immunol 2015, 34(1): 82-100.
[18] Xia Y, He F, Wu X, et al. GABA transporter sustains IL-1beta production in macrophages. Sci Adv, 2021, 7(15).
[19] Hirano S, Zhou Q, Furuyama A, Kanno S. Differential Regulation of IL-1beta and IL-6 Release in Murine Macrophages. Inflammation, 2017, 40(6): 1933-1943.
[20] McNeill E, Crabtree MJ, Sahgal N, et al. Regulation of iNOS function and cellular redox state by macrophage Gch1 reveals specific requirements for tetrahydrobiopterin in NRF2 activation. Free Radic Biol Med, 2015, 79: 206-216.

[21] Bosca L, Zeini M, Traves PG, Hortelano S. Nitric oxide and cell viability in inflammatory cells: a role for NO in macrophage function and fate. Toxicology, 2005, 208(2): 249-258.
[22] Hua KF, Wang SH., Dong WC., Lin CY, Ho CL, Wu TH. High glucose increases nitric oxide generation in lipopolysaccharide-activated macrophages by enhancing activity of protein kinase C-alpha/delta and NF-kappaB. Inflamm Res, 2012, 61(10): 1107-1116.
[23] Woodburn SC, Bollinger JL, Wohleb ES. The semantics of microglia activation: neuroinflammation, homeostasis, and stress. J Neuroinflammation, 2021, 18(1): 258.
[24] Liu X, Wang Y, Zeng Y, et al. Microglia-neuron interactions promote chronic itch via the NLRP3-IL-1beta-GRPR axis. Allergy, 2023, 78(6): 1570-1584.
[25] Lopez-Rodriguez AB, Hennessy E, Murray CL, et al. Acute systemic inflammation exacerbates neuroinflammation in Alzheimer's disease: IL-1beta drives amplified responses in primed astrocytes and neuronal network dysfunction. Alzheimers Dement, 2021, 17(10): 1735-1755.
[26] Jang DI, Lee AH, Shin HY, Song HR, Park JH, Kang TB, et al. The Role of Tumor Necrosis Factor Alpha (TNF-alpha) in Autoimmune Disease and Current TNF-alpha Inhibitors in Therapeutics. Int J Mol Sci, 2021, 22(5).
[27] Bras JP, Bravo J, Freitas J, Barbosa MA, et al. TNF-alpha-induced microglia activation requires miR-342: impact on NF-kB signaling and neurotoxicity. Cell Death Dis, 2020, 11(6): 415.
[28] Wang H, Chen Y, Liu X, et al. TNF-alpha derived from arsenite-induced microglia activation mediated neuronal necroptosis. Ecotoxicol Environ Saf, 2022, 236: 113468.
[29] Zhang J, Li L, Xiu F. Sesamin suppresses high glucose-induced microglial inflammation in the retina in vitro and in vivo. J Neurophysiol, 2022, 127(2): 405-411.
[30] Chen X, Shi C, He M, et al. Endoplasmic reticulum stress: molecular mechanism and therapeutic targets. Signal Transduct Target Ther, 2023, 8(1): 352.