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Digital Transformation Restructures the Industrial landscape: the Co-evolution of Cconomy, Technology and Security

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KEYWORDS

Digital transformation;

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Collaborative Evolution;

Digital sovereignty;

China-Belarus cooperation

ABSTRACT

In the global wave of digital economy, digital transformation has become a core driving force for reshaping national industrial patterns and enhancing global competitiveness. Taking China and Belarus as case studies, this paper constructs a three-dimensional co-evolutionary framework of economy, technology, and security (ETS) to explore the complex interaction mechanisms of economic efficiency improvement, innovation-driven development, and security risk prevention during the transformation process. The research reveals that China has achieved comprehensive restructuring through its scale advantages and systematic strategies, while Belarus has developed specialized IT service industries by leveraging professional breakthroughs and geostrategic bridging. The practices of both countries demonstrate that successful digital transformation requires dynamic balance and coordinated development of ETS, particularly under the context of the "Digital Silk Road," where international cooperation, standard alignment, and institutional innovation are key to achieving a sustainable and secure digital future.

INTRODUCTION

In the 21st century, next-generation information technologies represented by cloud computing, big data, artificial intelligence, and the Internet of Things are driving global digital transformation at an unprecedented pace and scale. This transformation transcends mere technological application — it represents a fundamental restructuring of industrial value chains, business models, and even social governance systems (Vial, 2019)[1]. As nations pursue economic benefits and technological innovation, they must confront the accompanying challenges of cybersecurity and data sovereignty.

This paper proposes an economic-technological-security (ETS) co-evolutionary framework, arguing that digital transformation is not a one-dimensional development but a dynamic process where these three elements constrain and promote each other. The improvement of economic efficiency relies on technological breakthroughs, while the healthy development of technology and economy must be based on security. We select China (the worlds second-largest economy and a leader in the digital economy) and Belarus (an important member of the Eurasian Economic Union and a high-quality IT service exporter) as comparative cases to reveal the common patterns and differentiated paths of digital transformation under different national conditions and scales, and to explore how China and Belarus can achieve ETS co-development under the "Digital Silk Road" framework.

1.Economic dimension: Digitalization reshaping the industrial value chain

The reconstruction of economic pattern by digital transformation is mainly reflected in two aspects: the disruptive improvement of the efficiency of traditional industries (industrial digitization) and the large-scale development of emerging digital industries (digital industrialization).

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1.1.China: Endogenous growth driven by scale and ecological construction

Chinas digital economy continues to grow, exceeding 56 trillion yuan in 2023, accounting for over 40% of GDP (China Academy of Information and Communications Technology, 2024)[2]. The core characteristics of its economic transformation path are the dual-wheel drive of "platform empowerment" and "industrial internet":

1. The Internets Reverse Impact: Leading platforms like Alibaba and Tencent leverage their vast user data and algorithmic expertise to extend services into traditional sectors such as industry and agriculture. For instance, e-commerce platforms and mobile payment systems have restructured retail and financial value chains. Meanwhile, logistics networks like Cainiao have enhanced supply chain efficiency through IoT technology, fundamentally reshaping distribution patterns.
2. Intelligent upgrading of manufacturing: China has vigorously promoted the construction of "industrial internet", achieving large-scale flexible production and personalized customization in manufacturing through platforms such as COSMOPlat and Rootcloud, significantly enhancing the added value and global competitiveness of traditional industries (Zhou & Li, 2023)[3]. This model leverages the vast domestic market to achieve a rapid closed loop of technological application and economic benefits.

1.2.Belarus: Specialization Breakthrough and Export Orientation

Although Belaruss economic size is much smaller than Chinas, its digital strategy focuses on the export of high-value-added IT services. The Minsk High-Tech Park (HTP) is the core carrier of this strategy, successfully attracting and nurturing hundreds of internationally renowned software development and IT outsourcing companies through tax incentives and talent policies (Karpovich, 2022)[4].

Belaruss economic performance is as follows:

1. Strong IT service exports: The IT industrys contribution to national GDP and service trade exports continues to grow, serving as a key driver for economic growth and diversification. It demonstrates strong international competitiveness in areas such as game development, embedded systems, and cybersecurity software.
2. "Digital Corridor" positioning: Belarus leverages its geographical advantages and EU membership to serve as a digital service hub connecting Eastern and Central European markets, delivering customized technological solutions to global clients.

2.Technical dimension: Dual challenges of independent innovation and collaborative standards

2.1.China:Systematic layout of new infrastructure

Chinas investment in the technological dimension exhibits systematic and forward-looking characteristics:

1. Infrastructure leadership: In the construction of new infrastructure such as 5G, fiber optic networks, cloud computing, and artificial intelligence computing centers, China maintains a global leading position. For example, the "East Data West Computing" project optimizes the layout of computing resources to provide fundamental support for the development of the digital industry nationwide.
2. Core Technology Breakthrough: Facing external technological constraints, China has implemented a "bottleneck" technology breakthrough plan, increasing R&D investment in artificial intelligence chips, operating systems, industrial software, and quantum computing to achieve technological autonomy and control (Li & Wang, 2021)[5].
3. Standard-led capacity enhancement: Chinese enterprises actively participate in the formulation of international standards, particularly in fields such as 5G and the Internet of Things, where they hold a large number of core patents, enhancing their voice in the global digital technology ecosystem.

2.2.Belarus: Talent Advantage and "Light Asset" Innovation

Belaruss technological strengths are primarily rooted in software engineering and talent development. Its high literacy rate and robust STEM education system have cultivated a substantial pool of high-caliber IT professionals,

forming the bedrock of its digital economy competitiveness. Belarus adopts a light-asset technology strategy, focusing on software algorithms, application development, and data science rather than heavy-asset hardware manufacturing. Its innovation path emphasizes deep integration with international tech communities through high-tech parks, leveraging global advanced technologies to achieve efficient secondary and applied innovation (Karabanova, 2023)[6].

2.3.Technological Synergy: The Practice of China-Belarus Industrial Park

The "Jushi" project in the China-Belarus Industrial Park demonstrates the potential of technological collaboration. China provides 5G network deployment and digital infrastructure, while Belarus offers software talent and system integration capabilities. However, technological collaboration also faces challenges, such as compatibility issues between Chinas promoted industrial internet standards and Belaruss Eurasian Economic Union standards, which require both sides to promote "mutual recognition of standards and flexible alignment" through a joint technical committee.

3.Security dimension: The balance between digital sovereignty and risk prevention and control

The security risks brought by digital transformation are systemic, transnational and dynamic, involving cyber attacks, data leakage, supply chain disruption and algorithmic ethics. The security dimension is crucial to maintaining the stable operation of the economy and the healthy development of technology.

3.1.China: Digital governance system under the overall national security concept

China has elevated digital security to an important component of its overall national security concept, establishing a legal framework of "three laws in one" (the Cybersecurity Law, the Data Security Law, and the Personal Information Protection Law), with the core logic being "sovereignty first, development guaranteed":

1. Data classification and grading: Strict classification and grading management shall be implemented for data related to national security, the lifeline of the national economy and public interests, and important data and core data shall be stored in China.
2. Critical Information Infrastructure Protection (CIP): By conducting security reviews and promoting domestic alternatives, we aim to reduce reliance on foreign technologies in critical sectors, thereby strengthening supply chain resilience and achieving self-reliance.
3. Cross-border data flow regulation: Regulate sensitive data outbound activities through a security assessment mechanism, aiming to balance global cooperation and national sovereignty protection.

3.2.Belarus: Security strategy in an open economy

As an open small economy, Belarus prioritizes multilateral cooperation and legal compliance in security matters (Shamov & Popov, 2020)[7].

1. Strengthening the legal framework: Belarus has enacted the Law on Information, Informatization and Information Protection and regulations on personal data protection, aiming to align with the EUs GDPR and the Eurasian Economic Unions norms to attract international IT investment.
2. Regional security alliance: Belarus strengthens cooperation with Russia, China and other partners in the field of cyber security, jointly combating cybercrime and responding to geopolitical-driven cyber threats.
3. Balance between sovereignty and openness: Belarus seeks a delicate balance between limited sovereignty and market openness by emphasizing the protection of critical information infrastructure on the one hand and providing relatively flexible data processing environment for foreign investment through high-tech park policy on the other hand.

4.ETS Co-evolution Mechanism and Implications from the China-Belarus Case

The coordinated evolution of economy, technology and security is the key to the success of digital transformation. The three are not mutually opposed, but interdependent: economic benefits provide funding for technology research and development, technological progress improves productivity and security protection, and improved security guarantees create a stable trust environment for economic

and technological development.

4.1.Pathways of Co-evolution

The path of co-evolution between China and Belarus is different due to their national conditions:(Attachment 1).

4.2.ETS Synergy in Chinas Digital Collaboration

The collaboration between China and Belarus under the Digital Silk Road framework exemplifies the value of institutional innovation in ETS coordination. The China-Belarus Industrial Park serves as a prime example, establishing bilateral compliance agreements for cross-border data flows through a regulatory sandbox mechanism. This approach not only safeguards data sovereignty and security but also reduces compliance costs while promoting the application of 5G and IoT technologies, effectively achieving a virtuous cycle among the three elements [8].

Conclusion

Digital transformation is a systematic project to reshape the global industrial landscape, with its success lying in achieving coordinated evolution of economy, technology, and security. China, leveraging its massive market scale and national strategic support, has demonstrated comprehensive restructuring capabilities from foundational technologies to application ecosystems; Belarus, on the other hand, has found its positioning in the open international market by focusing on IT talent and specialized services.

Global digital transformation should focus on three key priorities: First, advancing inclusive development to bridge the digital divide and ensure SMEs and underdeveloped regions can benefit from digital dividends. Second, promoting global digital governance through enhanced international coordination on cross-border data flows, AI ethics, and cybersecurity standards to prevent excessive data silos. Third, driving institutional innovation by transforming security constraints into innovation catalysts through regulatory sandboxes and public-private partnerships.Only when the dynamic balance between efficiency, innovation and security is found, and a collaborative development ecosystem is built through institutional design and international cooperation, can digital transformation truly become a key force to promote sustainable and resilient development of the global economy.

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Attachment 1

Table.1.

Dimension	The collaborative path of China	Belarusian collaborative pathways	Inspiration
Economy	Scale-driven, platform ecosystem construction, to achieve endogenous growth.	Specialization and talent-driven, economic diversification through IT service exports.	Large countries focus on ecology, while small countries focus on specialization and niche markets.
Technology	New infrastructure takes the lead, and we pursue independent control of core technologies.	The software has deep expertise, focusing on application innovation and international cooperation.	Those with sufficient funds pursue full stack technology, while those with limited resources pursue breakthroughs in key points.
Safe	Sovereignty comes first, build a legal system, and implement life-cycle regulation.	We will bring laws into line with international standards and hedge risks through regional cooperation.	Security must be embedded in economic activity, not imposed as a restriction.

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A Study Of Synergistic Mechanisms Between Corporate Digital Empowerment And Sustainable Governance Under The Global Sustainable Development Agenda

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KEYWORDS

Global sustainable Development agenda; Digital empowerment; Sustainable Governance ; Governance logic; Capability evolution

ABSTRACT

Global climate change, resource pressures and social inequality have turned sustainable development into a central concern for firms. The United Nations 2030 Agenda for Sustainable Development and related carbon reduction targets require corporate governance to move beyond a narrow financial focus toward a balance between economic, environmental and social outcomes. At the same time, digital technologies reshape corporate strategy and operations, but many studies still examine digital transformation and sustainable governance separately. This article develops a framework that explains how digital empowerment can support corporate sustainable governance under the global sustainable development agenda. It defines corporate digital empowerment and sustainable governance, adopts a perspective that combines governance logic with capability evolution, and argues that digital empowerment can reshape information structures and decision procedures, support a shift in governance logic, and strengthen sustainable governance capabilities and performance.

INTRODUCTION

The spread of sustainability standards and ESG disclosure requirements has strengthened expectations that firms internalise environmental and social externalities and report their performance in a transparent way[1]. In parallel, digital technologies transform how firms collect and process information, reduce information asymmetries and monitoring costs, and make it feasible to track environmental and social indicators[2]. What remains insufficiently understood is how these digital possibilities can be organised to support coherent sustainable governance rather than simply adding new tools to existing arrangements. This study therefore asks how corporate governance logic is changing under the global sustainable development agenda, through which pathways digital empowerment influences governance logic and capability structures, and how firms can build a relatively stable synergistic relationship between digital empowerment and sustainable governance.

1.Theoretical Foundations And Analytical Perspective

The global sustainable development agenda is accompanied by policy instruments such as carbon pricing and green finance, and by ESG ratings, sustainability reports and mandatory disclosure regimes. These developments enable markets and other actors to monitor corporate environmental and social conduct and increase pressure for behavioural change[3]. In this institutional setting, firms need governance arrangements that can respond to external norms and stakeholder expectations and address environmental and social risks alongside financial performance.

Digital empowerment refers to the process through which firms, supported by digital technologies and infrastructure, collect, integrate and analyse data in order to adjust resource allocation, business processes and governance mechanisms[4]. It can strengthen the capacity to monitor

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environmental risks and supply chain emissions, support data driven decision making, and facilitate coordination across organisational levels and boundaries.

To analyse digital empowerment and sustainable governance within a unified framework, this study adopts an integrated perspective that combines governance logic with capability evolution. Governance logic refers to shared understandings and institutional rules concerning value priorities, goal setting and the allocation of rights and responsibilities. Capability evolution focuses on how firms build, combine and renew resources and capabilities in dynamic environments. Under the constraints of the global sustainable development agenda, firms are expected to shift from a purely financial logic to a more comprehensive logic that brings economic, environmental and social dimensions together. Digital empowerment can support this shift by altering information structures, decision procedures and organisational relationships.

2.Conceptual Definitions And Theoretical Framework

Corporate digital empowerment is defined as the process through which firms, under the support of digital technologies and infrastructure, systematically collect, integrate and analyse data, and on this basis adjust resource allocation, business processes and governance mechanisms to improve value creation and governance quality[5]. Sustainable governance is understood as a mode of corporate governance in which firms incorporate environmental and social objectives into governance structures and processes, and seek to improve economic, environmental and social performance in an integrated way[6]. It encompasses both the traditional configuration of corporate governance, in terms of board composition and ownership structures, and the newer governance practices of ESG indicator systems, sustainability reporting and stakeholder participation.

On the basis of these definitions, the study develops a framework for the synergistic mechanisms between corporate digital empowerment and sustainable governance. Digital empowerment alters information structures and decision foundations, and supports the restructuring of governance logic. Changes in governance logic then shape the evolution of sustainable governance capabilities through adjustments in strategic direction, organisational design and data governance arrangements.

3.Synergistic Mechanisms Between Digital Empowerment And Sustainable Governance

At the strategic level, digital empowerment enhances firms' ability to sense external risks and opportunities and to integrate sustainability factors into strategic goals. At the organisational level, it encourages the creation of sustainability committees or specialised units and supports data platforms that make cross departmental information sharing and coordination more effective. Environmental and social indicators can be embedded in the targets and performance reviews of business units, which strengthens the internal binding force of sustainable governance.

At the technological and data level, digital empowerment provides tools for sustainable governance. Sensors and Internet of Things devices can record energy use, emissions and equipment conditions, while data visualisation supports the interpretation of complex indicators. As relevant data accumulate, regulators, investors and social organisations can obtain more timely information on corporate sustainability performance. Firms need sound data governance rules that ensure data quality and security and align technical systems with institutional requirements. Digital platforms and open data can also enable broader participation by external stakeholders and embed firms in wider sustainability governance networks.

Conclusion

This article develops a theoretical framework that explains how corporate digital empowerment can support sustainable governance under the global sustainable development agenda. It shows how digital empowerment reshapes information structures and decision making, supports a shift in governance logic from a purely financial orientation toward a broader value orientation, and contributes to the development of sustainable governance capabilities and to more coherent performance across economic, environmental and social dimensions. The analysis suggests that firms planning digital transformation should integrate sustainability objectives into strategic and performance systems, adjust governance structures and processes to reflect sustainability requirements, and strengthen digital infrastructure and data governance to support multi stakeholder collaborative governance.

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Enhancement of Concrete Durability with Waterborne Acrylic Resin: A Comprehensive Review

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KEYWORDS

Water-based acrylic resin;

Synthesis method;
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Durabili

ABSTRACT

As an environmentally friendly polymer material, water-based acrylic resin has shown significant application advantages in the fields of construction, coatings, and concrete in recent years due to its molecular properties of using water as a solvent Compared with traditional solvent based resins, water-based acrylic resins use water as the solvent and have a lower content of volatile organic compounds, effectively alleviating construction pollution problems and in line with the development trend of green building materials Based on the analysis of the current development status and trends of the construction industry, this article mainly summarizes the development process and synthesis technology of water-based acrylic resin, and focuses on explaining its dual path application mechanism of external coating protection and internal mixing modification in concrete engineering By forming a hydrogen bond cross-linking network and interface strengthening effect, water-based acrylic resin can significantly improve the compressive strength, impermeability grade, and shrinkage cracking resistance of concrete matrix, achieving synergistic optimization of mechanical properties and durability Finally, future research directions were discussed.

INTRODUCTION

Amid the global consensus on environmental protection and the steady implementation of sustainable development strategies, the growth of traditional solvent-based coatings has become increasingly constrained due to their high safety risks and environmental pollution. Against this backdrop, the vigorous development of low-toxicity, eco-friendly coating products has emerged as an inevitable trend and urgent demand for the industry. As a key component of water-based coatings, waterborne acrylic resins have gained extensive application in numerous traditional fields, such as coatings, adhesives, and papermaking, owing to their non-toxic, harmless, and environmentally friendly properties. In recent years, their applications have further expanded into emerging domains, including concrete and construction, demonstrating remarkable prospects and potential. These resins are poised to become a driving force in the green transformation of related industries in the future.

As one of the most essential construction materials, the durability, impermeability, and aesthetic properties of concrete critically determine the service life and visual quality of buildings [1-2]. However, inherent limitations such as high porosity, proneness to carbonation, and susceptibility to cracking render concrete vulnerable to environmental degradation, leading to performance deterioration and increasingly prominent durability issues.

In this context, modified cement-based materials characterized by synergistic performance enhancement have emerged as a research focus. Among these, acrylic resins have drawn considerable attention due to their exceptional adhesive properties, weather resistance, and chemical stability. Recent years have witnessed extensive studies by domestic and international scholars on the application of

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waterborne acrylic resins in concrete and construction domains, yielding significant progress. Nevertheless, challenges persist in this field. This paper systematically examines the research advancements in waterborne acrylic resin applications, encompassing surface coatings and internal admixtures for concrete, starting from their synthesis processes. Furthermore, it analyzes future development trends to provide theoretical foundations and technical references for further research and practical implementation of waterborne acrylic resins in concrete-related applications.

1.Synthesis of Waterborne Acrylic Resins

Waterborne acrylic resins are typically synthesized through copolymerization of acrylic acid, methacrylic acid, their esters, or other derivatives. The structural diagram of their fundamental components[3] is illustrated in Figure 1 , while Figure 2 outlines the synthesis methodologies, which primarily include emulsion polymerization, solution polymerization, bulk polymerization, and soap-free emulsion polymerization.

1.1.Emulsion Polymerization

Emulsion polymerization[4] stands as one of the most prevalent methods for synthesizing waterborne acrylic resins. This method employs water as the dispersion medium, where monomers are dispersed via emulsifiers and polymerized under initiators. Commonly used monomers encompass acrylic acid, methyl methacrylate, butyl acrylate, and styrene. Typical emulsifiers include anionic (e.g., sodium dodecyl sulfate) or nonionic emulsifiers, while water-soluble initiators such as ammonium persulfate or potassium persulfate are frequently utilized.

Li et al.[5] developed an acrylic-PDMS composite emulsion by blending modified polydimethylsiloxane (PDMS) with acrylate monomers through emulsion polymerization. Experimental characterization revealed that the cured coatings derived from this composite emulsion exhibited low surface tension, enhanced toughness, and exceptional weather resistance, demonstrating promising applications in corrosion protection. Notably, this method features mild reaction conditions, operational safety, and scalability for industrial production. The resultant acrylic resin emulsion demonstrates superior film-forming capability, weather resistance, and adhesion, making it suitable for eco-friendly coatings and environmentally benign adhesives

1.2.Solution Polymerization

Solution polymerization[6] involves dissolving monomers in organic solvents, initiating polymerization via initiators, and subsequently removing the solvent or replacing it with water to obtain waterborne acrylic resins. Common solvents include acetone, methyl ethyl ketone (MEK), and isopropanol. Similar to emulsion polymerization, acrylic acid and its ester monomers are typically selected, with oil-soluble initiators such as azobisisobutyronitrile (AIBN) or benzoyl peroxide (BPO) being commonly employed. Fan et al. [7] synthesized an acrylic resin with a solid content of up to 80% using methyl methacrylate (MMA), methyl acrylate (MA), hydroxyethyl methacrylate (HEMA), n-butyl acrylate (BA), and styrene as monomers via solution polymerization. This method is conducted under an inert gas atmosphere, where monomers and initiators are added to the solvent and heated to initiate polymerization. The reaction proceeds rapidly with controllable molecular weight, making it suitable for synthesizing high-solid-content resins

1.3.Bulk Polymerization

Bulk polymerization [8] is a solvent-free process where monomers are directly heated to initiate polymerization. Monomers and initiators are mixed and heated to a specific temperature to drive the reaction. Chen et al. [9] optimized reaction parameters, including temperature, initiator dosage, and monomer ratios, through orthogonal experiments. The resulting products were characterized using Fourier transform infrared spectroscopy (FTIR) and gel permeation chromatography (GPC). Experimental results indicated that the optimal conditions were a reaction temperature of 80°C, initiator dosage of 0.5%, and monomer ratio of MMA:BA:AA = 60:30:10. The optimized resin exhibited excellent film-forming properties and adhesion. This method offers simplicity in process and high-purity products, though challenges such as intense exothermic reactions and difficulties in temperature control must be addressed.

1.4.Emulsifier-Free Emulsion Polymerization

Emulsifier-free emulsion polymerization [10] employs functional monomers (e.g., acrylic acid, methacrylic acid) instead of traditional emulsifiers to stabilize the emulsion,

enabling polymerization without surfactants. Wang et al. [11] determined the optimal formulation for resin synthesis via single-factor and orthogonal experiments: MMA:BA:AA = 50:40:10, reaction temperature of 80°C, and reaction time of 4 h. The resulting resin displayed uniform particle size distribution, a tensile strength of 15 MPa, and an elongation at break of 300%. Qiu Shiqi et al. [12] further modified the emulsifier-free emulsion polymerization process by introducing crosslinking agents and functional monomers, enhancing the adhesive properties, water resistance, and chemical resistance of the resin. This method eliminates the need for conventional emulsifiers, yielding products with higher purity, improved water resistance, enhanced stability, and superior environmental compatibility.

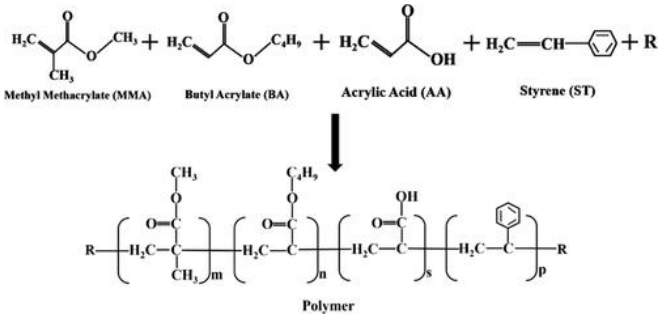

Fig.1. Waterborne acrylic resin and its monomer structure[3]

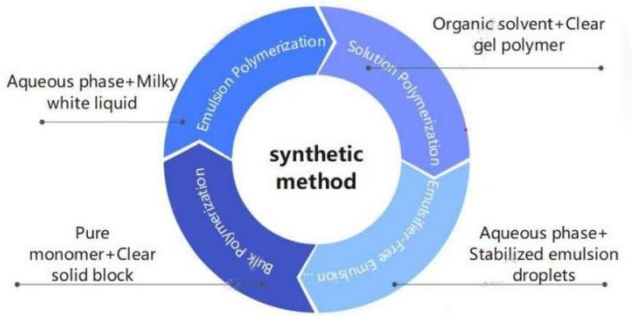

Fig.2. Synthetic method

2.Incorporation of Waterborne Acrylic Resin in Concrete

The application of waterborne acrylic resin in concrete is widespread, primarily attributed to its environmental friendliness, durability, and excellent adhesion [13 – 17]. The internal incorporation method [18], as a core technique for modifying concrete with waterborne acrylic resin, involves adding pre-treated resin emulsions into the concrete mixture through precise proportioning design. Leveraging the flexible chain segments and active functional groups of the resin molecules, nanoscale three-dimensional penetration within the pores of the concrete is achieved. This process enhances the concrete's compactness, compressive strength, and bonding performance.

2.1.Enhancement of Bonding Performance

The overall strength of concrete primarily depends on the bonding strength between the cement paste and aggregates. Poor bonding can result in weak interfacial connections, leading to crack formation at the interface under stress. This premature structural failure prevents full utilization of material strengths, thereby reducing the compressive, tensile, and shear strength properties of concrete [19 – 22]. Numerous factors influence concrete bonding performance. For instance, inadequate mixing during construction causes uneven distribution of concrete components, compromising the adhesion between cement paste and aggregates. This results in excessive pores and voids within the concrete, diminishing its overall strength and bonding capacity.

The long-chain polymer structure of acrylic resin endows it with excellent adhesion, flexibility, and transparency. Its low viscosity enables effective penetration into the micro-pores of concrete, thereby enhancing interfacial adhesion. Guo et al. [23] introduced epoxy resin into the molecular structure of waterborne acrylic resin. By combining epoxy resin with aqueous dispersion techniques, they synthesized waterborne epoxy-acrylic resin, which was subsequently incorporated into concrete as a hydrogel during the mixing process. As shown in Figure 3, when the resin content reached 5%, the tensile bond strength of the resulting concrete measured 4 – 5 MPa. The internal incorporation of waterborne acrylic resin emulsion into concrete acts as a "bridge" to fill the interfacial transition zone between cement paste and aggregates. This densifies the internal structure of concrete, significantly improves bonding performance, and reduces the risk of debonding [24 – 26]

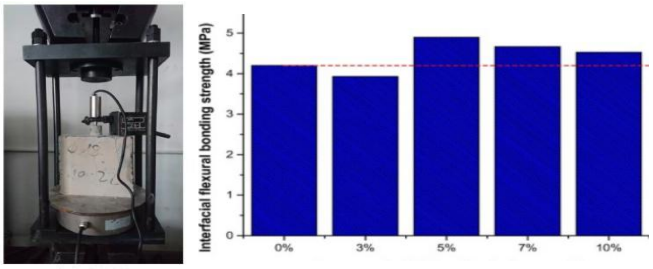

Fig.3. Concrete bonding performance testing[23]

2.2.Optimization of Mechanical Properties

Poor mechanical performance of concrete, caused by issues

in raw materials, construction processes, environmental factors, or long-term degradation, may lead to safety hazards or economic losses [27].

When acrylic resin is incorporated into concrete in emulsion or solution form, it forms continuous polymer films during hardening. These films fill capillary pores and microcracks within the cement mortar, effectively dispersing and transmitting stress. Cui Weirong et al. [28] demonstrated that adding 3% waterborne acrylic resin via internal incorporation improved interfacial bond strength by 25% – 40%, thereby enhancing concrete's compressive strength (by approximately 10% – 15%) and splitting tensile strength (by approximately 15% – 20%). Current modification techniques for waterborne acrylic resin, such as fluorination, silane coupling, or incorporation of nanomaterials (e.g., steel fibers, rubber), have matured. Liang Bingkang et al. [29] synthesized silane coupling agent-modified waterborne acrylic resin, where the hydrolysis of silane formed Si – O – Si crosslinked structures. This modification significantly enhanced the bonding between the resin and concrete aggregates. Experimental tests revealed a 12.4 MPa increase in flexural strength and a 159% improvement in tensile strength. The incorporation of acrylic resin into concrete enhances compactness, reduces porosity, and strengthens compressive capacity. Furthermore, crack suppression improves flexural and tensile performance [30 – 32].

2.3.Improvement of Freeze-Thaw Resistance

Traditional cement-based matrices exhibit high brittleness and lack ductile buffering capacity, rendering them vulnerable to repeated stresses during freeze-thaw cycles. This results in poor freeze-thaw resistance. In northern road engineering, combined salt-freeze effects accelerate concrete deterioration, significantly shortening service life and increasing maintenance costs.

Waterborne acrylic resin possesses exceptional elasticity and deformation capacity. When internally incorporated into concrete, it forms a flexible network structure that absorbs energy through elastic deformation during stress concentration caused by freeze-thaw cycles, thereby delaying crack propagation. Shi et al. [33] experimentally demonstrated that ordinary concrete exhibits a mass loss rate >5% after 50 freeze-thaw cycles, whereas concrete with 10% acrylic resin shows a mass loss rate <2% and modulus retention >85% even after 100 cycles. In a practical case in China [34], 12% acrylic resin-modified concrete was used for permafrost road repair on the Qinghai-Tibet Highway. The freeze-thaw resistance increased from 50 to 200 cycles, extending the maintenance interval by threefold. Internal incorporation of acrylic resin provides an effective solution for enhancing concrete's freeze-thaw resistance, toughness, and impermeability. However, challenges such as cost, long-term stability, and material compatibility must be addressed for large-scale applications [35].

3.External Coating Application of Waterborne Acrylic Resin in Concrete

Concrete, when exposed to air over extended periods, is susceptible to water infiltration and chemical corrosion (e.g., chloride ions, acid rain). These factors trigger electrochemical corrosion chain reactions within the pore solution of concrete, accelerating steel reinforcement rusting and matrix dissolution, thereby shortening structural service life. The external coating method [36], as an innovative surface protection technology, involves uniformly applying synthesized waterborne acrylic resin emulsions onto concrete surfaces via brushing or spraying. After natural drying or curing, a dense, continuous molecular-level protective film is formed. Leveraging high crosslinking density and low surface energy, this film establishes a multifunctional barrier system with carbonation resistance, corrosion protection, and anti-fouling properties, achieving "one-coat multi-functionality" for concrete surface protection [37-38]. This method is primarily employed for rapid repair and long-term preservation of existing structures.

3.1.Improvement of Carbonation Resistance

The carbonation mechanism of concrete [39] involves the reaction of carbon dioxide with calcium hydroxide (a cement hydration product) to form calcium carbonate and water, reducing concrete alkalinity. This process destabilizes the passive film on steel reinforcement, leading to corrosion. Waterborne acrylic resin inhibits carbonation through physical isolation, chemical modification, and microscopic repair:

Physical Isolation:The cured coating forms a continuous film that seals surface micropores and microcracks, blocking CO_2 and moisture diffusion pathways. Experimental data indicate that the CO_2 diffusion coefficient of coated

concrete is reduced by 80% – 90%. Fan et al. [40] compared coated and uncoated concrete samples by applying waterborne acrylic resin emulsion and testing chloride ion penetration resistance after 12 – 270 days of salt corrosion. As shown in Figure 4, at a depth of 5 mm, chloride ion content in uncoated specimens exceeded 6000 mg/kg, whereas coated specimens exhibited levels below 3500 mg/kg.

Chemical Modification:Carboxyl groups in the resin react with Ca^{2+} in concrete to form organic-inorganic composites (e.g., calcium acrylate), enhancing coating adhesion and preventing delamination. Wang Si et al. [41] synthesized siloxane-modified waterborne acrylic resin via emulsion polymerization. When siloxane content reached 8%, the coating demonstrated optimal thermal stability, water resistance, and carbonation resistance.

Microscopic Repair:Certain waterborne acrylic resins contain microencapsulated healing agents that release reactive substances upon microcrack formation. These substances react with infiltrating CO_2 to generate calcium carbonate, enabling self-healing. Song et al. [42] evaluated the protective effects of modified waterborne acrylic resin and epoxy resin by applying them to concrete specimens and conducting salt freeze-thaw cycling tests. Chloride ion penetration depth and content measurements revealed that specimens coated with modified waterborne acrylic resin exhibited significantly slower chloride ingress and delayed failure compared to epoxy-coated specimens.

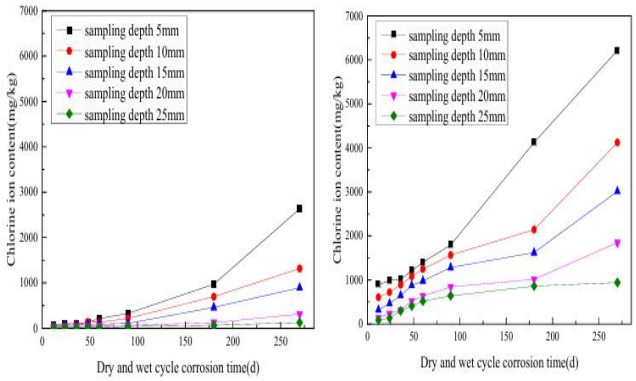

Fig.4. Comparison chart of concrete's resistance to chloride ions[40]

3.2.Enhancement of Elastic Recovery Capability

Elastic recovery capability [43] refers to the ability of a material to return to its original state after deformation under stress. Concrete, as a brittle material, inherently contains numerous microscopic defects, leading to poor elastic recovery. When subjected to external forces, concrete struggles to rebound, often resulting in irreversible permanent deformation or even cracks. These cracks act as "channels," allowing water and harmful substances to infiltrate the concrete matrix. Such ingress can corrode reinforcing steel, triggering expansion-induced cracking, which further propagates the damage in a vicious cycle, severely compromising the structural integrity of concrete [44-46].

By applying a waterborne acrylic resin coating to the concrete surface, a flexible protective layer is formed, enhancing the elastic recovery capability of concrete through both physical and chemical mechanisms [47-49]. Zheng et al. [50] synthesized a waterborne acrylic resin with excellent weather resistance and chemical stability via free-radical solution polymerization for concrete crack repair. Experimental results demonstrated that the resin achieved autonomous crack healing at the early stages of crack formation, significantly improving concrete durability. Peng Jiaming et al. [51] evaluated the performance of waterborne acrylic resin as a concrete sealer. Their study revealed that the resin effectively filled surface pores, enhancing waterproofing and stain resistance. However, the practical application of waterborne acrylic resin coatings still requires optimization in terms of weather resistance, adhesion, and compatibility with specific environmental and engineering requirements.

3.3Improvement in Anti-Fouling and Aesthetic Properties

The capillary pores and microcracks in concrete readily adsorb pollutants such as dust, oil stains, and microorganisms, leading to surface staining. In humid environments, these pores become breeding grounds for microbes, causing discoloration and mildew growth [52-54]. By incorporating low-surface-energy modifiers (e.g., fluorine or silicone) into the resin, a "lotus leaf effect" [55] can be imparted to the coating, enabling self-cleaning properties when applied to concrete. Peng Panpan et al. [56] enhanced the hydrophobicity of coatings by introducing silicone-modified polyurethane. When the silicone-polyurethane content reached 3%, the modified waterborne acrylic resin exhibited exceptional performance (Figure 5): a contact angle of 96.1°, an elongation at break

of 385%, and a tensile strength of 9.4 MPa. Salt spray tests confirmed that the coated concrete surface remained smooth and free of scaling.

Traditional concrete lacks color diversity and textural design, while modern architectural demands increasingly emphasize aesthetics, particularly in public spaces or corporate settings, where visually appealing structures enhance overall image and market appeal. Jana et al. [57] synthesized silicone-modified waterborne acrylic resin and explored its application in decorative concrete coatings, including colored flooring and stone-like finishes. The modified resin demonstrated excellent decorative performance and environmental compatibility, making it suitable for diverse architectural scenarios. These case studies validate the practicality and reliability of waterborne acrylic resin as a concrete coating. Furthermore, the resin can be blended with pigments to create colored concrete flooring, achieving a dual upgrade in both "functionality and aesthetics" [58-61].

Sample	adhesion/grade	hardness	water contact angle
PISA0	4	HB	67.8
PISA1	3	HB	74.3
PISA2	2	H	86.6
PISA3	1	2H	96.1
PISA4	1	2H	97.2

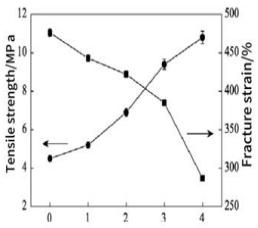

Fig.5. XPerformance tests under different polyurethane contents[56]

3.4.Enhancement of Corrosion Resistance

Concrete corrosion [62] is a global issue prevalent in various infrastructures, with common types including steel reinforcement corrosion, microbial corrosion, and chemical-physical erosion. The eco-friendly and water-resistant properties of waterborne acrylic resin make it directly applicable to processes requiring corrosion resistance. Data [63] indicate that submerged pier concrete of a cross-sea bridge, subjected to chloride ion erosion, exhibited over 15% steel reinforcement corrosion rate and surface longitudinal cracks along the reinforcement bars after five years. After applying two coats of waterborne acrylic resin with a thickness of 0.4 mm, monitoring results over a decade revealed a chloride ion penetration depth of only 1.8 mm and a steel reinforcement corrosion rate of <3%, with the expected service life extended to 30 years. This demonstrates a viable solution for enhancing concrete durability.

Traditional acrylic resins remain limited in corrosion protection applications. Researchers have optimized their performance through modification to overcome their single-function drawbacks. Bi et al. [64] successfully synthesized an acrylic resin with exceptional water resistance, corrosion resistance, and thermal stability by introducing octafluoropentyl methacrylate and phosphate ester-based anticorrosion functional monomers. Compared to unmodified acrylic resin, the modified resin exhibited an increased contact angle from 40 ° to 120 ° and an elevated initial decomposition temperature from 264 ° C to 305 ° C. Fan et al. [65] developed a corrosion protection strategy for concrete by incorporating microcapsules containing corrosion inhibitors into waterborne acrylic resin. Electrochemical impedance spectroscopy (EIS) analysis of samples immersed in sodium chloride solution and deionized water (Figure 6) showed that the microcapsule-coated samples exhibited higher inert corrosion potentials of −532 mV_{SCE} and −513 mV_{SCE} compared to the control group, providing a novel approach for preparing eco-friendly, stable, and corrosion-resistant waterborne acrylic resins.

Although modified acrylic resin coatings demonstrate excellent anticorrosion performance in laboratory settings, their long-term protective mechanisms in real-world engineering applications require further investigation [66-68]. Concrete structures are exposed to complex environmental stressors such as ultraviolet radiation, sand/gravel impact, and temperature fluctuations, which challenge the durability of these coatings.

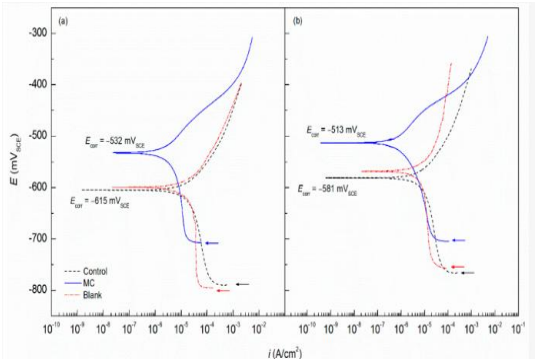

Fig.6. Comparison of potentiodynamic polarization curves[65]

4.Future Perspectives

While waterborne acrylic resins demonstrate significant advantages in concrete applications, several technical

challenges remain unresolved. Concurrently, their water resistance and weather resistance require further enhancement to meet long-term durability demands under extreme environmental conditions [69-72]. The interfacial bonding mechanisms between waterborne acrylic resins and concrete also necessitate in-depth investigation. The selection of internal incorporation versus external coating strategies for concrete applications is evaluated as follows:

1. Internal Incorporation: Preferred for high-demand structures, such as marine engineering projects, chemical plant saline-alkali grounds, or environments with prolonged exposure to corrosive media, where comprehensive improvements in concrete durability and mechanical performance are required, and budgets permit.
2. If the main purpose is for surface protection, quick repair, or low-cost improvement (such as crack sealing, waterproofing, or protecting garage floors from oil stains), prioritize exterior coatings;
3. (3) Hybrid Approach: For extreme scenarios, a combination of internal incorporation (to enhance bulk concrete properties) and external coating (to reinforce surface protection) can be adopted.
4. Efforts should be intensified to advance research on the composite applications of waterborne acrylic resins. In-depth exploration of their integration with nanomaterials and fiber-reinforced materials is essential to unlock synergistic enhancement potential and drive material innovation. Currently, the interaction mechanisms of waterborne acrylic resins within concrete systems remain incompletely understood, and the performance evaluation of resin-concrete composites requires further behavioral studies to establish a robust scientific assessment framework.In the realm of novel concrete technologies, accelerated exploration of waterborne acrylic resins in permeable and lightweight concrete is imperative. Research should focus on elucidating their mechanisms for optimizing pore structures and enhancing performance, thereby facilitating the development of new building materials that integrate environmental sustainability with high performance. These advancements will propel the construction materials industry toward greener practices and high-performance solutions.

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Comparative Analysis Of Challenges In Electric Power Transition Under The Global Low-Carbon Economy Initiative

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KEYWORDS

Power system transition;

Energy trilemma, comparative analysis;

Multinational collaboration

ABSTRACT

In the global transition to a low-carbon economy, structural contradictions within electric power systems have become a core obstacle to achieving climate goals. Using Russia, Germany, and China as case studies, this article employs a comparative case study approach to analyze the inherent conflicts in resource-dependent, policy-driven, and scale-economic transformation models. Moving beyond descriptive analysis, the study identifies a central trilemma of "security, equity, and sustainability" that underpins these challenges. It proposes two pathways—"dynamic adaptive policy design" and "a new international cooperation framework"—to address the central question:"How to construct a multinational collaborative path for power system transformation under the global low-carbon economy initiative."

INTRODUCTION

Global climate governance faces unprecedented urgency. According to the IPCC Sixth Assessment Report, global CO_2 emissions must be reduced by 43% by 2030 to limit temperature rise to 1.5° C [1]. However, the low-carbon transition of energy and power systems shows significant divergence: developed countries face technical and economic challenges in "replacing existing capacities," while developing nations struggle with the conflict between "growing demand" and "emission reduction responsibilities" [2]. While extant literature extensively documents the technological and economic hurdles in individual national contexts, a critical gap remains in comparative analyses that dissect the underlying political economy and structural contradictions across divergent transition models. Russia, Germany, and China exemplify resource-dependent, policy-driven, and scale-economic transformation models, respectively. Their divergent paths reflect deep-seated contradictions in the global transition. This article aims to fill this gap by conducting a comparative analysis of these three paradigmatic cases, with the ultimate goal of exploring feasible multinational collaborative pathways. The central research question is: "How can multinational collaboration overcome the divergent challenges in power system transformation under the global low-carbon economy initiative?"

2.Energy Development Challenges in the Low-Carbon Economy

2.1.Russia: Lock-in Effects of Fossil Fuel Dependencyand Geopolitical Isolation

As the world's third-largest natural gas producer, Russia is trapped in a "self-reinforcing cycle" driven by a political economy centered on hydrocarbon revenues and the power of entrenched energy oligarchs. in 2023, gas export revenues reached $340 billion (45% of the national budget), yet only 3% was invested in renewables [5]. Siberia's "blue hydrogen project," based on methane reforming with CCUS, revealed that producing 1 ton of hydrogen consumes 9 tons of freshwater and emits 8.5 tons of CO_2 (60% captured) [5]. Additionally, every 10,000-ton production capacity reduces local river flow by 3.7%, creating long-term ecological risks. EU carbon tariffs and technological sanctions further restrict Russia's hydrogen export market, exacerbating its technological isolation and limiting

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access to critical clean energy technologies.

2.2.Germany: Industrial Backlash from Aggressive Coal Phase-Out Amidst Domestic Political Pressures

In 2023, Germany's energy transition costs became evident: industrial electricity prices surged to € 0.42/kWh, prompting BASF to shift € 4 billion in investments to China [6]. This policy-driven transition, largely propelled by the political influence of the Green Party and a strong environmental movement, has created a tangible conflict between environmental goals and industrial competitiveness. To compensate for baseload shortages, lignite usage increased by 13%, raising the power sector's carbon intensity to 0.48 tons CO_2 /MWh (+5% from 2022) [3]. High renewable penetration (50 GW planned) coupled with low grid flexibility led to 15 TWh of curtailed wind energy (7% of annual output) [3]. These contradictions highlight the tension between ambitious domestic climate policy and the realities of a globalized economy.

2.3.China: Scale Dilemmas in Coal Power Transition <mark>and Subnational Governance Challenges

Despite exceeding 1,000 GW in renewable capacity, coal still accounts for 53% of power generation [7]. The central government's "dual carbon" goals often clash with subnational priorities of economic growth, fiscal stability, and employment. Provinces like Shanxi and Inner Mongolia face "structural unemployment": closing 1 GW of coal capacity displaces 2,000 workers, while renewables absorb only 30% [4]. The Ordos "coal+CCUS" pilot project shows capture costs of $65/ton — triple local carbon prices. Regional disparities are stark: coal contributes 30% of Shanxi's GDP, while eastern provinces like Zhejiang better integrate renewables, revealing a core challenge of equitable and coordinated transition across a vast and heterogeneous nation.

3.Comparative Analysis of Transition Pathways and Core Contradictions

3.1.Transition Pathway Comparison

Pathway	Case Study	Challenges	Cross-Country Comparison
Renewable Scaling	Germany: North Sea Wind Farms (50 GW)	Land-use conflicts: 178 km²/GW vs. fishing opposition	China: Qinghai solar land costs rose 300% (2018–2023)
Cleaning Conventional Energy	Russia: Siberian Blue Hydrogen	CCUS costs: $65/ton (30% profitability)	China: coal+CCUS raises generation costs by 40%
End-Use Electrification	China: 120M EVs by 2030	Grid peak demand: 8 GW gap requires $20B investment	Germany: heat pumps cost €15,000/household → low adoption

Table.1. Transition Pathway Comparison

3.2.Core Contradictions: The "Security-Equity-Sustainability" Trilemma

The case studies reveal that transition challenges are not merely technical or economic, but manifestations of a deeper "trilemma" between Energy Security, Socioeconomic Equity, and Environmental Sustainability.

Russia's pathway is predominantly constrained by the security imperative of maintaining fossil fuel revenue, which directly conflicts with long-term sustainability and, due to ecological impacts, local equity.

Germany's model prioritizes sustainability through aggressive decarbonization, which has undermined its economic security (industrial competitiveness) and raised equity concerns regarding energy affordability.

China's scale-driven approach is caught between the equity demands of regional development and employment and the sustainability goals of the central government, with energy security currently still reliant on coal.

These contradictions reveal that the transition is not a mere technological substitution but a complex socio-political struggle among vested interests, technical path dependencies, and geopolitical constraints that can be usefully framed through this trilemma lens (Fig. 1).

4.Recommendations for Multinational Collaboration

4.1.Dynamic Adaptive Policy Design

Country	Policy Recommendation	Measures
Germany	Carbon Price-Competitiveness Mechanism	Allocate 30% of carbon tax revenue to subsidize energy-intensive industries
China	Differentiated Coal Phase-Out	Set transition periods (15 years for Shanxi, 7 years for Zhejiang)
Russia	Fossil Revenue Transition Fund	Mandate gas exporters to invest 5% of income in hydrogen R&D

Table.2. Dynamic Adaptive Policy Design

4.2.A New International Cooperation Framework: Potentials and Pitfalls

While politically challenging, innovative cooperation frameworks are essential. The following proposals are presented with an explicit analysis of their feasibility constraints.

Eurasian Green Energy Corridor: Link German wind and Siberian solar via China-Russia HVDC technology. (Feasibility Challenge:) This requires standard harmonization and, most critically, a resolution to current geopolitical sanctions and trust deficits, which presently render this proposal largely aspirational.

Debt-for-Transition Mechanism: Allow developing nations to convert 30% of fossil debt into clean energy investments with IMF guarantees. (Feasibility Challenge:) This depends on the willingness of creditor nations and complex multilateral negotiations, but offers a tangible incentive for Global South participation.Global Green Hydrogen Certification: Track carbon footprints via blockchain and establish mutual recognition standards. (Feasibility Challenge:) This is a more immediately actionable proposal, though it faces hurdles in technical standardization and competing national interests.

Conclusion

The global low-carbon transition faces profound contradictions between unified goals and divergent paths, conceptualized in this study as the "security-equity-sustainability" trilemma. Solutions require balancing:Short-term: Accept "imperfect transitions" (e.g., China’s gradual coal phase-out, Germany’s reserve coal capacity) as necessary compromises within the trilemma.Mid-term: Foster pragmatic collaboration via mechanisms like the potentially more viable "Debt-for-Transition Mechanism," while building trust for larger projects.Long-term: Develop "bridge technologies" like long-duration storage and hydrogen metallurgy to ultimately reconcile the trilemma.The success of the global transition is contingent upon a delicate balance among policy, technology, and, most importantly, a clear-eyed recognition of the competing imperatives that define each nation's journey.

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Dilemmas and Breakthrough Paths in the Management of Physical Fitness and Health of College Students from the Perspective of Smart Sports

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KEYWORDS

Smart sports;
Physica fitness;
Health management;
Challenges;
Optimization paths

ABSTRACT

With the rapid development of information technology, smart sports has gradually become an important means to improve the efficiency and quality of physical health management for college students. It utilizes technologies such as the Internet of Things, big data, and artificial intelligence to monitor and analyze students' health status in real time and provide personalized guidance. However, Chinese universities still face challenges in the application of smart sports, including insufficient technical support, data management issues, and an imperfect policy system. This paper analyzes the application difficulties of smart sports in college physical health management through a combination of literature analysis, questionnaire surveys, and in-depth interviews. Based on domestic and international university cases, it proposes breakthrough paths such as optimizing technology application, improving management systems, increasing student participation, strengthening data protection, and increasing financial investment. Research shows that smart sports has broad application prospects, but to achieve comprehensive promotion, challenges in technology, management, and funding need to be overcome to promote the scientific and personalized management of college students' physical health.

INTRODUCTION

With the rapid development of information technology, smart sports, as an important component of modern sports management and education, is gradually becoming an innovative means to improve the efficiency and quality of students' physical health management [1]. By combining big data, the Internet of Things, and artificial intelligence technologies, smart sports can monitor, analyze, and manage students' physical health status in real time, providing personalized health advice and guidance, and promoting the scientific management and precise intervention of physical health [2]. However, the physical health status of university students in my country still faces many challenges. According to recent health survey data, many university students suffer from declining physical fitness, insufficient exercise, and unscientific health management, especially against the backdrop of exam pressure, academic burden, and a fast-paced lifestyle, where these health management problems are becoming increasingly serious [3]. Therefore, how to promote the improvement of students' physical health through technological means has become an important issue that urgently needs to be addressed in the education field. This study focuses on the perspective of "smart sports," exploring the dilemmas and breakthrough paths in the physical health management of university students. By analyzing the current application status of smart sports and exploring its potential in physical health management, it aims to provide scientific theoretical support and practical solutions for higher education and management.

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1.Research Ideas and Methods

This study explores the challenges and breakthroughs in the physical health management of Chinese university students from the perspective of smart sports. Through literature analysis, it outlines the theoretical foundation, development trends, and current application status of smart sports in physical health management, and identifies the main problems existing in current management models. To further validate and supplement the literature review, this study conducted an empirical survey of university faculty, students, and administrators in China using a combination of questionnaires and in-depth interviews. The study selected 15 universities from both northern and southern China, including 3 teacher training colleges, 3 comprehensive universities, and 9 sports colleges, to ensure the representativeness of the sample in terms of region and type. A total of 350 questionnaires were distributed to university students and 46 to faculty and administrators, with 364 valid responses received, representing a 93% effective response rate.

2.Research Content

2.1.Theoretical Framework and Current Application Status of Smart Sports

2.1.1.Theoretical Framework

Smart sports utilize technologies such as the Internet of Things (IoT), big data, and artificial intelligence (AI) to monitor, analyze, and manage sports activities in real time, aiming to enhance the scientific, personalized, and intelligent aspects of exercise [4]. Its core framework includes data collection and monitoring, big data analysis and personalized exercise plans, intelligent feedback, and intelligent management (Fig 1). Exercise data is collected in real time through IoT devices and wearable devices. The system provides personalized exercise plans based on the analysis results and adjusts them according to real-time data. Intelligent feedback mechanisms help provide immediate health guidance, while the smart sports platform provides decision support for schools or sports institutions, helping administrators monitor students' physical health in real time and develop scientific intervention strategies.

Fig.1. Core Components of Smart Sports Management

2.1.2.Current Application Status

In some developed regions of southern China, the application of smart sports equipment has been gradually promoted. For example, wearable devices such as smart treadmills, smart body composition analyzers, and smart bracelets are widely used to track students' exercise status and record key data such as heart rate, steps, and exercise intensity. Some universities have also combined smart sports with health management systems to develop big data-based physical health assessment and intervention platforms. By integrating and analyzing student health data, schools can accurately grasp students' physical condition and provide customized exercise and health advice for each student. Although the application of smart sports has made some progress in universities in some developed regions, overall, it still faces problems such as untimely equipment updates, insufficient technical support, and uneven student participation. Many schools' equipment still faces challenges of low accuracy and poor stability, and some students have low awareness and participation in smart sports. However, with the continuous development of technology and gradual investment of funds, smart sports are gradually becoming an important tool for improving students' physical health management in universities in these regions, laying the foundation for future promotion in a wider area [5].

2.2.Challenges in the Application of Smart Sports in Physical Fitness Management of Chinese Universities

2.2.1.Technological Application Bottlenecks

The survey revealed that most universities still use traditional physical education classes, while a few

universities have outdated modern equipment that cannot meet current technological requirements, resulting in insufficient accuracy and stability of data collection. Furthermore, some universities have not yet established comprehensive data collection and analysis platforms, leading to the inefficient integration and real-time processing of large amounts of health data, and a lack of effective data support. This limits the application effect of smart sports and consequently affects the overall development of physical fitness management in universities.

2.2.2.Insufficient Management System and Policy Support

In some universities, the management system for smart sports is not yet perfect, lacking a clear institutional framework. This problem is particularly prominent in universities in northern China. Many schools lack dedicated teams or departments responsible for the planning and implementation of smart sports, leading to a disconnect between technological applications and actual needs. Collaboration between sports management departments and information technology departments is poor, lacking effective communication and resource integration, which further restricts the construction and application of smart sports.

2.2.3.Student Participation and Health Awareness Issues

Students' health management awareness remains relatively weak, especially in physical health management. Many students lack the motivation and awareness to actively participate. Although smart sports equipment can provide personalized health advice and feedback [6], many students do not fully recognize the importance of these functions and often neglect the importance of regular exercise and health management. Many students only pay attention to their health during physical examinations, lacking sustained attention to exercise and health management at other times, resulting in the application of smart sports failing to reach its maximum effectiveness. Furthermore, the health management platforms of most universities have relatively basic functions, and the depth and accuracy of personalized services are far from expected. The exercise plans provided by the platform are too simplistic and fail to be precisely adjusted according to students' specific health conditions and exercise habits, resulting in insufficient student engagement and satisfaction when using these platforms.

2.2.4.Data Privacy and Security Issues

With the popularization of smart sports technology, data privacy and security issues have become a major challenge [7]. The core of smart sports relies on the collection and analysis of large amounts of health data, which includes students' physical condition, exercise habits, and health problems personal privacy information [8]. How to effectively utilize this data while ensuring data privacy has become a crucial issue facing smart sports. Research has found that many universities have failed to take sufficient data protection measures, making students' health data vulnerable to leakage. Improper use or leakage of this data will seriously infringe on student privacy.

2.2.5.Funding and Resource Allocation Issues

Research has found significant differences in the application of smart sports in universities in the north and south, especially in local or economically disadvantaged institutions where insufficient funding is more prominent. This funding constraint restricts the construction and upgrading of smart sports equipment and technology platforms. Even with some funding support, how to rationally allocate resources and ensure equipment maintenance and timely technology upgrades remains a critical issue that urgently needs to be addressed. Aging equipment and lagging technology updates not only directly affect the application effect of smart sports but also reduce the student user experience, thus hindering the comprehensive promotion of smart sports in university physical health management (Fig2).

Fig.2. Challenges in Smart Sports Implementation

2.3.Exploring Breakthrough Paths under the Vision of Smart Sports

By analyzing the challenges of smart sports in university physical health management, the following breakthrough paths are proposed. First, optimizing technology application should involve strengthening the construction of intelligent hardware facilities, improving the accuracy of data collection and analysis, and promoting the integration of IoT, big data, and artificial intelligence technologies to create a personalized health management platform. Second, regarding the improvement of the management system, a sound management system for smart sports needs to be established, promoting collaboration among schools, teachers, and students to ensure the effective implementation of technology. Enhancing student participation should be achieved through health education and training to strengthen students' health management awareness and promote their active participation. Regarding data security, a sound data protection system should be established to ensure the security and privacy of students' health data. Finally, regarding funding and resource allocation, increased investment and rational resource allocation are needed to ensure equipment updates and maintenance, promoting the comprehensive application of smart sports. Through the implementation of these measures, the application effect of smart sports in university physical health management will be significantly improved.

3.Results and Discussion

The application of smart sports in university physical health management presents both significant opportunities and challenges. Based on the data collected through questionnaires and in-depth interviews, several key findings emerged.

3.1.Effectiveness of Smart Sports in Enhancing Health Management

The survey results showed that universities that have implemented smart sports systems have seen improvements in students' physical health management. A significant proportion of students reported feeling more motivated to exercise and monitor their health due to the personalized health advice and feedback provided by smart sports equipment. The integration of IoT devices, big data, and artificial intelligence enabled real-time monitoring of students' physical conditions, which helped in identifying health issues early and provided timely interventions. However, despite these positive outcomes, the overall effectiveness of smart sports was limited by several factors, including the lack of comprehensive infrastructure and low participation among students. While some universities have successfully implemented smart sports equipment, others face challenges in the reliability and accuracy of these devices, particularly when it comes to tracking more complex health metrics.

3.2.Technological Challenges

The analysis revealed that technological application bottlenecks remain one of the most significant challenges. In many universities, outdated equipment and lack of proper integration of smart systems hinder the effectiveness of health monitoring. Many institutions still rely on traditional physical education methods, with minimal integration of new technologies. Furthermore, data collection platforms are often underdeveloped, resulting in slow processing and poor integration of the data collected from various smart devices. This issue not only affects the quality of health management but also limits the system's capacity to provide personalized health plans for students.

3.3.Insufficient Management Systems and Policy Support

Another major finding was the lack of a standardized management system for smart sports. Most universities have not yet established clear policies or departments specifically dedicated to smart sports implementation. This has resulted in fragmented management and poor coordination between different departments, such as physical education and information technology. Effective communication between these departments is critical to ensure the smooth implementation and monitoring of smart sports systems. Additionally, the absence of a coherent policy framework makes it difficult to integrate smart sports into the broader educational strategy.

3.4.Student Participation and Health Awareness

The research highlighted that student participation in smart sports remains relatively low. While some students expressed interest in using smart sports equipment, many were not fully aware of the benefits of such systems. A significant number of students reported a lack of long-term commitment to their health management. This is primarily due to insufficient health education and awareness about the importance of regular physical activity beyond the mandatory physical exams. As a result, many students only engage with smart sports systems during health assessments, rather than consistently using them for health management throughout the semester.

3.5.Data Privacy and Security Concerns

Data privacy and security emerged as a critical issue in the implementation of smart sports. With the collection of sensitive health data, including heart rates, exercise patterns, and other personal health information, universities face the challenge of protecting students' privacy. Many respondents expressed concerns about the potential misuse or unauthorized sharing of their health data. While some universities have taken steps to ensure data protection, many have yet to implement comprehensive data security measures.

3.6.Financial and Resource Constraints

The survey results also revealed that financial constraints pose a significant obstacle to the broader implementation of smart sports in universities, particularly in economically disadvantaged regions. Many institutions struggle to secure sufficient funding for purchasing smart sports equipment, maintaining infrastructure, and updating technology. This issue has led to discrepancies in the quality of smart sports programs across different universities, further exacerbating inequalities in access to high-quality physical health management.

To enhance the effectiveness of smart sports and address current challenges, universities should prioritize investments in modern technology and the development of robust data platforms. A standardized management system, supported by dedicated teams for planning, implementation, and monitoring, is crucial. Strong collaboration between physical education and IT departments is essential for success. To boost student engagement, targeted health education programs should be introduced, emphasizing the long-term benefits of fitness and the importance of consistent health monitoring. In addition, universities must establish secure data protection protocols to ensure privacy and build trust with students. Finally, securing increased funding through government grants, private partnerships, and alumni donations will support the ongoing development and expansion of smart sports programs. By taking these steps, institutions can unlock the full potential of smart sports and significantly improve student health management.

Conclusion

This study explored the current status and challenges of smart sports in university physical health management and proposed corresponding breakthrough paths. Although smart sports has potential in improving student physical health management, it still faces challenges in technology, management, and funding. By optimizing technology application, improving management systems, increasing student participation, and ensuring data security, the comprehensive application of smart sports can be effectively promoted, thereby enhancing the effectiveness of university physical health management. In the future, with technological advancements and policy support, smart sports will play an even greater role in university health management.

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A Review of Environmental Responsibility of Logistics Enterprises

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KEYWORDS

Logistics enterprises;
Tenvironmental responsibility;
Evaluation indicators

ABSTRACT

This paper reviews the evaluation of environmental responsibility fulfillment by logistics enterprises and the research on the construction of related index systems. In terms of evaluation, it is closely related to the assessment of corporate social responsibility. After the "triple bottom line" theory was proposed, the importance of environmental responsibility assessment has become increasingly prominent. The construction of the indicator system can be divided into two paths: one is not to rely on existing mature theories, and the other is to depend on mature theories such as the "triple bottom line" and ESG. Among them, the "triple bottom line" theory is widely applied, and some scholars have expanded or screened its dimensions. ESG theory is also applied to related performance evaluations, while the data envelopment rule provides guidance for the construction of input-output indicator systems. Based on the above review, the article puts forward further research ideas.

INTRODUCTION

In recent years, although the policy level has successively issued documents such as the "14th Five-Year Plan for the Development of Modern Logistics" and the "Opinions on Accelerating the Green Development of Modern Logistics", clearly putting forward specific requirements for the green transformation of the logistics industry, and some leading enterprises have also fulfilled their environmental responsibilities by promoting new energy transportation capacity, optimizing transportation routes, and adopting circular packaging, from the perspective of the industry as a whole, There are still problems of imbalance and lack of systematicness in the fulfillment of environmental responsibilities by logistics enterprises[1]. Among them, the non-uniformity of the environmental responsibility indicator system, the blurring of evaluation standards, and the absence of core indicators have become key constraints. In the quantitative assessment of environmental responsibility, logistics enterprises of different regions and scales lack a unified yardstick. Some enterprises only measure their own performance with general expressions such as "reducing fuel consumption" and "lowering the amount of waste". It is difficult to accurately reflect the depth and actual effectiveness of environmental responsibility fulfillment. This confusion at the indicator level not only makes it difficult to quantitatively assess the effectiveness of enterprises' fulfillment of environmental responsibilities, but also brings many obstacles to policy supervision, industry benchmarking and social supervision. Moreover, it makes it hard for logistics enterprises to clearly identify their own shortcomings and improvement directions during the process of green transformation.

Against this backdrop, systematically sorting out and summarizing the current relevant indicators of environmental responsibility of logistics enterprises, clarifying the core dimensions, theoretical basis and practical application status of the indicator design, can not only accurately identify the common problems and individual differences in the industry's practice of environmental responsibility, but also provide strong support for logistics enterprises to clarify the key points of green transformation and for policymakers to improve the regulatory system This will further promote the coordinated development of environmental and economic benefits in the entire logistics industry, providing a solid guarantee for the implementation of China's green development strategy in the real economy.

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1.Evaluation Of Logistics Enterprises Related To The Fulfillment Of Environmental Responsibilities

1.1.Social Responsibility Evaluation

The relationship between the social responsibility evaluation of logistics enterprises and the fulfillment of their environmental responsibilities is inseparable [2]. Bowen (1953) first proposed the concept of corporate social responsibility, defining it as: the obligation of businesspeople to align with relevant policies, make corresponding decisions, and take ideal concrete actions in accordance with social goals and values [3]. At this point, the importance of enterprises fulfilling their environmental responsibilities has not yet been emphasized. It was not until Elkington (1998) proposed the "triple bottom line" theory composed of economic responsibility, environmental responsibility and social responsibility to construct the evaluation system of corporate social responsibility that people gradually paid attention to the evaluation of enterprises' environmental responsibility [4]. When studying the social responsibility evaluation of logistics enterprises, scholars employ various methods, but the selection of indicators is relatively similar. Luo et al. (2021) adopted the weighted method of mean square error index to analyze the performance of 74 enterprises in China's transportation industry from seven aspects: corporate governance, economic performance, environmental protection, basic human rights, product liability, fair operation, and community development [5]. Liang et al. (2023) evaluated 68 transportation enterprises from seven aspects: corporate responsibility governance, employee human rights, environmental protection, fair operation, product responsibility, community development, and economic contribution, using a combined approach to corporate social responsibility based on differences and similarities. Quan et al. (2022) evaluated the comprehensive efficiency of social responsibility of listed logistics enterprises based on the DEA-Malmquist model, establishing input and output indicators from the perspectives of customers, employees, and society [6].

1.2.Green Performance Evaluation

Green performance evaluation of logistics enterprises refers to the regular and irregular assessment and evaluation of their working capabilities, achievements in green logistics practices, as well as their contributions to the environment and social responsibility [7]. In foreign literature, the data enveloping model is a relatively common tool for evaluating the green performance of logistics enterprises. Data enveloping, as a non-parametric evaluation method, is mainly used to assess the relative efficiency of decision-making units with multiple inputs and multiple outputs. Fathi et al. (2022) evaluated the sustainability performance of transportation enterprises through a novel robust two-stage network data envelope model [8]. Fathi et al. (2024) developed a set of general weight models through a two-stage network data envelope model and Shannon entropy to further deepen the research on the green performance evaluation of logistics enterprises by Fathi et al. (2022) [9]. In addition, the Malmquist index was initially proposed by Malmquist in 1953. Caves, Chris tensen and Diewert began to apply this index to the measurement of changes in production efficiency in 1982 [10]. In the green evaluation of logistics enterprises, Mavi et al. (2019) used the ideal point method to derive the Malmquist productivity index and proposed a new dual-frontier data envelope universal weight model to evaluate the green performance of transportation enterprises [11].

2.The Construction Of An Indicator System For Logistics Enterprises Related To The Fulfillment Of Environmental Responsibilities

When building an indicator system related to the fulfillment of environmental responsibilities for logistics enterprises, the construction paths can be divided into two major categories: One is the method of independent design and construction based on specific scenarios or actual needs, rather than directly relying on existing mature theoretical frameworks; Another category is to fully utilize and integrate mature theories (such as the triple bottom line theory, ESG theory, etc.) as guiding principles and theoretical foundations, and construct an evaluation index system through systematic methods. This classification method aims to emphasize whether a time-tested and widely recognized theoretical system has been adopted as support and guidance during the construction process. In foreign literature, some have not constructed an index system based on existing theories. For instance, Kumar (2020) evaluated logistics suppliers from aspects such as internal and external

management practices, freight distribution and fleet operation practices, and green knowledge management practices [12], and did not use mature theories to assist in building an evaluation index system. It is quite common in foreign literature to construct an index system based on existing theoretical frameworks. When evaluating the green development level of logistics enterprises, the triple bottom line principle is widely adopted as a framework. This principle emphasizes that when measuring the performance of enterprises, a comprehensive consideration of the economy, society and environment should be emphasized. It is necessary to comprehensively evaluate the performance of the three dimensions of economy, society and environment, so as to comprehensively assess the sustainable development capacity of logistics enterprises and the effectiveness of their green transformation. Scholars such as Fulzele (2023) and Prabodhika (2022) have used economic, social and environmental indicators to evaluate the green development of logistics enterprises [13, 14]. Some scholars have expanded the dimensions of the triple bottom line principle on its basis. As Zhang and Mohammad (2024) introduced the dimension of "sustainable development innovation" on the basis of the triple bottom line principle [15]; Mohammadkhani and Mousavi (2023) introduced the "risk" dimension; Daimi (2023) introduced the "institutional" dimension [16]. Some scholars, such as Prabodhika (2022), have excluded the "economic" dimension indicators from the triple bottom line principle to reflect that the constructed indicator system deeply focuses on the fulfillment of enterprises' social and environmental responsibilities [17]. During the continuous development of the triple bottom line principle, some scholars have proposed the ESG theory (environment, Society and Governance) based on the triple bottom line principle [18]. As Zhang (2024) employed the data enveloping model to assess the sustainable development performance of China's international trade ports based on environmental, social and governance factors [19]. In addition to the guiding role of ESG theory in building an indicator system, when using the data envelopment method, as input-output indicators need to be constructed, it also plays a guiding role in the construction of the indicator system.

3.Review of Literature Research

3.1.Overall Research Status

In terms of the content of index evaluation, current research at home and abroad mainly focuses on the social responsibility evaluation of logistics enterprises, green performance evaluation, and the selection evaluation of green logistics suppliers, etc. In the evaluation of social responsibility, early attention was focused on enterprises' response obligations to social goals and values. Subsequently, with the proposal of the "triple bottom line" theory, the consideration of environmental responsibility was gradually strengthened. Green performance evaluation focuses on the comprehensive performance of logistics enterprises in green logistics practices, covering their contributions to the environment and social responsibility. The selection and evaluation of green logistics suppliers emphasize the balance between economic and environmental responsibility benefits, screening out potential suppliers that not only meet business needs but also align with the concept of green development.

In terms of the construction methods of the indicator system, they can be divided into two types. One type does not rely on mature theoretical frameworks, but independently designs indicators based on specific scenarios or actual needs, and combines the operational practices of logistics enterprises to extract evaluation dimensions. Another category relies on mature theories (such as the triple bottom line theory, ESG theory, and stakeholder theory) as guidance to systematically construct an indicator system. Among them, the triple bottom line theory is widely applied, and some studies have further expanded on its basis, such as introducing new dimensions like "innovation", "risk", and "institution". ESG theory integrates environmental, social and governance elements, providing a framework for the design of indicator systems. The stakeholder theory starts from the needs of the subjects, such as shareholders, employees, communities, etc. In addition, the data envelope model can only be used by constructing a system dimension with "input", "output" and "environmental factors" as variables, and thus also plays a guiding role in the construction of the indicator system.

3.2.Research Gap

Based on the above discussion, there are two possible areas

for optimization in the current construction of the environmental responsibility index system for logistics enterprises. On the one hand, at the level of indicator design, due to the differences in method selection and evaluation objectives, existing literature, especially domestic literature, mostly focuses on easily quantifiable dimensions such as equipment investment and operation processes, while paying insufficient attention to the core element of environmental management level. This leads to a structural imbalance in evaluation dimensions and makes it difficult to comprehensively reflect the level of enterprises' fulfillment of environmental responsibilities. On the other hand, at the level of research methods, the literature review stage generally lacks systematic literature analysis and retrieval strategies, such as not clearly defining the retrieval scope and not adopting scientific screening criteria. This may lead to limitations in the theoretical basis and literature support of some studies, which could affect the rigor and innovation of the conclusions.

Conclusion

This paper first classifies and sorts out the existing environmental responsibility indicators of logistics enterprises, and analyzes in detail the construction paths of the indicator systems in various types of literature, providing strong support for subsequent researchers to deepen related explorations. By further analyzing the gaps in current research, a brand-new direction is provided for the innovative construction of the environmental responsibility evaluation system of logistics enterprises, thereby better promoting the sustainable and healthy development of green logistics.

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A Study on the Driving Factors of Carbon Emissions from China's Transportation Sector

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KEYWORDS

Transportation carbon emissions;
Driving factors;
SPSS;
Stepwise regression method

ABSTRACT

The deep decarbonization of the transportation sector is of decisive significance for China to achieve its "dual carbon" strategic goals. The formulation of a scientific emission reduction path relies on the precise quantitative analysis of the driving factors of carbon emissions growth. This study systematically combed through China's macroeconomic, social and infrastructure data from 2004 to 2023, and selected 11 potential driving factors covering four dimensions: economic scale, industrial structure, population and society, and infrastructure. By using SPSS statistical software and comprehensively applying methods such as correlation analysis, curve estimation and multiple linear stepwise regression, a multi-factor prediction model for the turnover volume of each sub-sector of passenger and freight transportation was constructed for the first time in a systematic manner. The empirical results show that the output value of the secondary industry is the most stable core economic variable driving freight demand (especially railway and waterway transportation); the urbanization rate has a significant positive impact on freight (railway and air) and air passenger turnover volume, revealing the deep transportation demand brought about by spatial structure changes; port throughput, as an indicator of an outward-oriented economy and trade activity, is closely related to road freight and air passenger demand. This study identified and quantified the key macro drivers of transportation carbon emissions from the root cause of demand, not only providing a reliable quantitative tool for transportation demand prediction, but also offering solid empirical evidence and decision-making references for achieving source reduction through top-level design such as optimizing industrial layout, adjusting economic structure and guiding urbanization models.

INTRODUCTION

Under the urgent global agenda to address climate change and China's solemn commitment to peak carbon emissions by 2030 and achieve carbon neutrality by 2060, the green and low-carbon transformation of the transportation industry, as one of the fastest-growing sectors in energy consumption and carbon emissions, has become a national strategic focus. According to statistics, the carbon dioxide emissions from China's transportation sector have surged from 248 million tons in 2000 to 885.4 million tons in 2021, accounting for a continuously increasing proportion of the country's total carbon emissions[1]. Although the substitution paths of terminal technologies such as electric vehicles and hydrogen energy have attracted much attention, if the intrinsic driving force of transportation demand growth is ignored, the emission reduction effect of any technological route may be offset by the overall growth. Therefore, a thorough analysis and quantification of the underlying driving factors that affect transportation carbon emissions is a prerequisite for achieving deep decarbonization of the transportation system.

Existing research has yielded fruitful results in areas such as transportation carbon emission accounting[2-4], scenario forecasting[5-7], and emission reduction costs [8-13], widely adopting "top-down" or "bottom-up" approaches. However, there remains a notable gap in the systematic identification and quantitative attribution analysis of key drivers connecting the macro socioeconomic system with

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micro-level transportation emissions, particularly through rigorous statistical models for comprehensive multi-variable analysis. Most studies have only engaged in qualitative discussions or simple correlations, lacking measurements of net effects under the interference of multiple collinear factors.

In light of this, based on the Energy-Economy-Environment (3E) systems theory framework, this study views transportation carbon emissions as an outcome driven by the socioeconomic system. Utilizing the SPSS statistical analysis software, standardized statistical processing and modeling analysis were conducted on multidimensional panel data, aiming to achieve the following objectives: (1) identify key driving factors influencing the turnover of various transportation sectors from a pool of candidate variables; (2) establish quantitative forecasting models based on these key driving factors; and (3) interpret the underlying drivers of transportation carbon emissions growth from the demand-side perspective, thereby providing scientific support for formulating forward-looking and systematic emission reduction policies.

1.Research Methodology and Data Processing

This study adopts a "bottom-up" analytical paradigm. Transportation carbon emissions originate directly from the fuel consumption of various transport vehicles, which is jointly determined by the level of transportation activity (turnover of transportation sectors) and energy intensity. Among these, energy intensity is primarily influenced by technological progress, while the activity level is deeply constrained by the macro socioeconomic environment. Therefore, identifying and forecasting the activity level forms the basis for carbon emission prediction.

1.1.Variable Selection and Data Sources

Drawing on relevant domestic and international studies [14-22] and considering data availability, continuity, and representativeness, this study preliminarily selected 11 driving factors that may influence transportation turnover volume. These factors cover four major dimensions: Economic Scale Dimension: Gross Domestic Product (GDP), GDP per capita. Industrial Structure Dimension: Output value of the primary industry, secondary industry, tertiary industry, and the transportation sector. Population & Society Dimension: Total population, household consumption level, urbanization rate. Infrastructure Dimension: Railway operating mileage, cargo throughput of major coastal ports.

The historical data for all driving factors, as well as passenger and freight turnover volumes, span the period from 2004 to 2023. The baseline data are sourced from the *China Statistical Yearbook*, *China Transport Statistical Yearbook*, *China Ports Yearbook*, and the official database of the National Bureau of Statistics.

1.2.SPSS Analysis Methods

The entire research process is conducted using SPSS, with the main analytical methods including:

Normality Tests and Correlation Analysis:The Shapiro-Wilk (S-W) test is employed to assess the distribution pattern of the data. Based on the results, either Pearson or Spearman correlation coefficients are selected to preliminarily evaluate the strength of association between each driving factor and the turnover of each sector.

Forecasting of Driving Factors (Curve Estimation):To obtain future values for the driving factors, the "Curve Estimation" function in SPSS is utilized. Each driving factor is treated as the dependent variable and fitted against the time variable (year) using various functional forms (linear, logarithmic, quadratic, exponential, etc.). The optimal forecasting model is selected based on the highest R^2 value.

Core Model: Multiple Linear Stepwise Regression: This is the core of the research. Using the turnover of each transportation sub-sector as the dependent variable and the screened driving factors as independent variables, a stepwise regression method is applied to construct the forecasting model. This method automatically introduces and removes variables, effectively addressing multicollinearity issues, ultimately yielding a parsimonious and statistically significant model. The model's explanatory power is evaluated using the Adjusted R^2, its overall significance is tested via Analysis of Variance (ANOVA), the independence of residuals is assessed using the Durbin-Watson (D-W) statistic, and multicollinearity is diagnosed using the Variance Inflation Factor (VIF).

2.Empirical Results and Analysis

2.1.Data Foundation Tests and Correlation Analysis

Before conducting regression analysis, normality tests were performed on all variables. Taking freight railway turnover and its driving factors as an example, the Shapiro-Wilk test results indicated that the significance levels for most variables were greater than 0.05, suggesting they follow a normal distribution, with only a few variables such as "Population" being exceptions. This provides a basis for subsequently employing Pearson correlation analysis as the primary method.

Pearson/Spearman correlation analysis indicates (Table 1) that all pre-selected driving factors show significant correlations with freight railway turnover at the 0.01 level, with the absolute values of correlation coefficients mostly exceeding 0.8. This demonstrates that the preliminary variable selection is reasonable and provides a solid foundation for further in-depth regression analysis.

Variable	Railway Freight Turnover		Coefficient Type
	Significance (2-tailed)	Correlation Coefficient	
GDP	<0.001	.853**	K-S
GDP per Capita	<0.001	.857**	K-S
Population	<0.001	.774**	S-W
Household Consumption	<0.001	.834**	K-S
Primary Industry Output Value	<0.001	.864**	K-S
Secondary Industry Output Value	<0.001	.876**	K-S
Tertiary Industry Output Value	<0.001	.835**	K-S
Transportation Industry Output Value	<0.001	.847**	K-S
Urbanization Rate	<0.001	.820**	K-S
Railway Operating Mileage	<0.001	.797**	K-S
Port Cargo Throughput	<0.001	.833**	K-S

Table.1. Correlation Test between Driving Factors and Freight Railway Turnover

2.2. Identification of Key Driving Factors and Model Construction Based on Stepwise Regression

Taking freight railway turnover as an example, the SPSS stepwise regression process ultimately retained four variables, forming Model 4 (Table 2). The adjusted R-squared for this model is as high as 0.956, meaning the selected four variables explain 95.6% of the variation in freight railway turnover, indicating an excellent goodness-of-fit. The Durbin-Watson (D-W) value is 1.644, close to 2, suggesting no autocorrelation among the residuals. The ANOVA test shows an F-value of 105.223 ($p < .001$) for the model, indicating that the model as a whole is highly significant.

Model	R	R^2	Adjusted R^2	Standard Error
4	.983[d]	.966	.956	968.31953

Table.2. Summary of the Stepwise Regression Model for Freight Railway Turnover

The output value of the secondary industry and the urbanization rate are the core growth drivers: Their positive coefficients indicate that the deepening industrialization process and the rising urbanization level are the strongest macroeconomic forces driving the demand for railway freight. For every 100 million yuan increase in the output value of the secondary industry, railway freight turnover is expected to increase by 0.081 hundred million ton-kilometers.

The complex effects of population and railway operating mileage: Their negative coefficients may be related to multicollinearity among variables in the model and long-term structural changes. A possible explanation is that as population growth slows and the railway network becomes increasingly well-developed, the transportation efficiency per unit of operating mileage has improved, or substitution effects have emerged within the comprehensive transportation system, necessitating integrated analysis with other modes of transport.

3. Summary of Driving Factor Models for Each Transportation Sector

Using the same method, other passenger and freight subsectors were analyzed to obtain a series of key driver models, which are summarized in Table 3. The results show that the dominant driving factors vary significantly across different transportation sectors, reflecting different dimensions of economic activities.

Department	Branch	Fitting formula
Freight transport	Road	y=21100.812+0.171L-8228.589k
	Railway	y=367541.343+0.081f-3228.138k-3.154c+1919.86i
	Water	y=31088.501+0.198f
	Pipeline	y=-1002.001+0.007L
	Air	y=-273.002+8.392i

Passenger transport	Road	y=31981.123+0.041L-4534.178k
	Railway	y=3909.719-0.619e+0.041L+0.339h
	Water	y=66.262-0.003e
	Air	y=-1710.358-0.361e+0.035L+2.058d-0.052a

Table 3. Summary of Key Driving Factors and Regression Models for Turnover in Passenger and Freight Sectors

In the table:
a: GDP
c: Population
d: Resident Consumption
e: Output Value of the Primary Industry
f: Output Value of the Secondary Industry
h: Output Value of the Transportation Industry
i: Urbanization Ratio
k: Railway Operating Mileage
L: Port Cargo Throughput
The results indicate:

1.Dominance of Industrial Structure: The output value of the secondary industry is not only the core driver for railway freight but also the sole significant driving factor for waterway freight. This clearly corroborates China's role as the "world's factory," highlighting the high synchronization between the cross-regional and import/export logistics of bulk raw materials and finished products with the development of heavy and chemical industries.

2.Comprehensive Impact of Urbanization: The urbanization rate drives not only railway freight but also serves as a key factor for aviation freight, reflecting the increasing demand for timeliness in logistics of high-value-added, lightweight products as cities develop. Simultaneously, it is one of the main drivers for aviation passenger transport, indicating frequent business and personnel exchanges between urban agglomerations.

3.Pull Effect of Trade and Consumption: Port cargo throughput, as a barometer of international trade, significantly influences road freight, railway passenger transport, and aviation passenger transport. This underscores the passenger and freight flow patterns shaped by both the export-oriented economy and internal consumption upgrading. The level of resident consumption has become a key explanatory variable for railway and aviation passenger transport, signaling rising demands for travel quality in a consumer-driven society.

4.Regulatory Role of Infrastructure: Railway operating mileage shows a negative correlation in the road freight model, possibly reflecting the substitution effect of an improved railway network on medium- to long-distance road freight flows. This demonstrates the inherent potential for optimizing the transportation structure.

Conclusion

Through systematic SPSS statistical analysis, this study has successfully identified and quantified the multi-dimensional key driving factors influencing China's transportation activity levels—the underlying source of carbon emissions. The main conclusions are as follows:

1. Driving factors exhibit clear sectoral heterogeneity: Different transportation sectors correspond to distinct dominant socioeconomic drivers. Freight sectors are closely tied to the industrialization process (secondary industry), while passenger sectors are more strongly linked to the upgrading of household consumption, trade activity, and urbanization-driven lifestyles.

2. The economic growth model defines the baseline for transportation carbon emissions: A development model dominated by the secondary industry inevitably entails rigid growth in the demand for bulk cargo transportation. This is the deep-seated structural reason behind the current high levels of transportation carbon emissions, particularly from freight.

3. Urbanization is a long-term growth driver: Urbanization not only directly stimulates passenger demand but also indirectly drives demand for time-sensitive freight by reshaping industrial layouts and consumption patterns. Its influence on transportation carbon emissions is therefore comprehensive and enduring.

This study primarily focuses on the identification of macro-level driving factors. In the future, the predicted activity levels from the model could be further integrated with energy-environment models such as LEAP. This integration could be used to quantify carbon emission pathways under different socioeconomic development scenarios and to evaluate the mitigation potential and cost-effectiveness of demand-side management policies, thereby constructing a more comprehensive decision-support system for transportation carbon emission reduction.

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Research Progress in Photothermal Self-Healing Coatings

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KEYWORDS

Intrinsic self-healing;

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Photo-responsive materials

ABSTRACT

Coatings serve as a critical barrier to protect substrates from corrosion, wear, and environmental degradation. Their ability to repair damage directly influences the service life of materials. Traditional coatings lack self-healing capabilities, making them susceptible to rapid performance degradation from micro-damage. Inspired by biological self-healing mechanisms, self-healing coatings have been developed. Among these, photothermal self-healing coatings have gained significant research interest due to their remote, precise, and controllable repair characteristics. This review systematically summarizes the healing mechanisms, material system design, and research progress of photothermal self-healing coatings. It focuses on the roles of carbon-based materials, MXenes, organic materials, and nanoparticles in photothermal conversion and repair behavior. The application prospects in aerospace, marine engineering, electronic devices, and other fields are discussed, along with future challenges. The advancement of photothermal self-healing coatings provides important theoretical support and technical pathways for designing high-performance intelligent protective materials.

INTRODUCTION

Coating technology is the primary defense for protecting materials against corrosion, wear, biofouling, and various environmental factors. The performance of coatings directly determines the service life and reliability of substrates. However, traditional coatings are essentially static, passive protection systems. Micro-cracks, surface scratches, and local delamination inevitably occur during processing, transportation, and long-term service [1]. These micro-damages not only become entry points for corrosive media or stress concentration, leading to exponential decay in protective performance, but their repair is often challenging, sometimes requiring operational shutdowns and resulting in significant economic costs and safety risks.

Inspired by the remarkable self-healing abilities in nature, materials scientists proposed the concept of smart self-healing materials [2]. Self-healing coatings, as pioneers of this concept, aim to mimic biological repair mechanisms, enabling materials to autonomously or externally stimulated recover their structure and function after damage [3].

Intrinsic self-healing relies on reversible chemical bonds within the polymer network, such as dynamic covalent bonds or non-covalent interactions, enabling repair under external stimuli and offering potential for multiple repair cycles.

Among the various damage-triggering methods, light energy has shown great potential due to its cleanness, easy control, and capability for remote and precise application. Particularly, the combined photothermal repair strategy, which converts light energy into thermal energy to activate dynamic reactions, enables non-contact, spatiotemporally controllable smart repair, opening new pathways for the practical application of self-healing coatings.

Therefore, in-depth research on photothermal self-healing coatings represents not only fundamental scientific exploration inspired by nature but also addresses the urgent need for long-term protection solutions in demanding service environments. This review aims to summarize research progress in photothermal self-healing coatings, systematically explain their core healing mechanisms and key material design strategies, and discuss current

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challenges and future trends.

1.Intrinsic Self-Healing

Intrinsic self-healing coatings incorporate dynamic reversible bonds into the polymer network, enabling molecular-level damage repair under external stimuli. The healing capability originates from the internal reversible cross-linked network, which can restore integrity and functionality through bond breakage and reformation. Based on the dynamic bond type, healing mechanisms primarily involve dynamic covalent bonds and non-covalent bonds [4,5]. Combining different dynamic bonds through multi-mechanism synergistic strategies is key to achieving high-performance self-healing [6].

1.1.Healing Mechanisms of Dynamic Covalent Bonds

Dynamic covalent bonds combine the stability of covalent bonds with the reversibility of dynamic reactions, providing a robust foundation for coating repair [7].

Disulfide bond systems enable network reconfiguration through reversible disulfide exchange or redox reactions. Studies show that synergizing disulfide bonds with other dynamic bonds significantly enhances performance [8]. Chen et al. constructed a dynamic supramolecular network containing disulfide metathesis and multiple hydrogen bonds, enabling precise tuning of material properties: disulfide bonds drove the self-healing process, while strong and weak hydrogen bonds contributed to mechanical strength and energy dissipation, respectively, markedly improving toughness [9].

Diels-Alder (DA) bond systems are based on the reversible cycloaddition between furan and maleimide, offering excellent thermal reversibility [10]. Truong et al. developed a DA-crosslinked polymer network that also benefited from hydrogen bonds provided by amide groups in the backbone. This DA-hydrogen bond synergy granted good mechanical properties and achieved approximately 85% strength recovery after cutting [11].

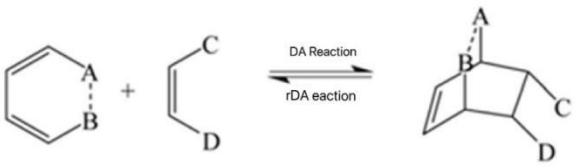

Fig.1.Diels-Alder reversible reaction mechanism

Imine bond systems, formed by condensation of aldehydes and amines, undergo dynamic exchange triggered by heat, pH, etc [12]. Yang et al. synthesized a self-healing Polydimethylsiloxane (PDMS) elastomer containing both strong ureido-based hydrogen bonds and dynamic imine bonds. Their synergy enabled 95% healing efficiency after 24 hours at room temperature, with the conjugated structure enhancing stability in humid environments [13].

1.2.Synergistic Effects of Non-Covalent Bonds

Non-covalent bonds, with their fast dynamic reorganization, are crucial in the initial stages of self-healing.

Hydrogen bonds, as fast, reversible physical cross-links, enable preliminary damage repair at room temperature. Peng et al. built a cross-linked network via multiple hydrogen bonds between tannic acid (TA) and linear waterborne polyurethane (WPU), producing self-curing cationic WPU/TAx composites. These achieved complete interfacial healing at room temperature, but required 7 days. At 50° C, healing time reduced to 3 hours, showing heat accelerates hydrogen bond reorganization [14].

Metal-ligand coordination bonds have moderate bond energy and can act as energy dissipation sites, enhancing toughness. Cui et al. introduced Zn^{2+} -imidazole coordination bonds into a supramolecular network combined with weaker urea hydrogen bonds, producing a self-healing material with excellent mechanical properties and high healing efficiency, where coordination bonds primarily provided tunable mechanical performance [15].

Despite their advantages, intrinsic self-healing materials face challenges for practical application: Firstly, dynamic covalent bond exchange often requires high activation energy, leading to slow healing rates unsuitable for rapid repair. Secondly, most systems need external energy input (e.g., heat) and exhibit limited healing efficiency at room temperature. These limitations restrict their use in applications requiring fast response and high mechanical performance [16].

2.Photothermal Self-Healing Coatings

A key technical bottleneck currently faced by self-healing polymer materials is the trade-off between mechanical properties and healing conditions: systems with excellent mechanical strength often require high healing temperatures, whereas those capable of rapid repair under mild conditions

typically exhibit insufficient mechanical performance. This trade-off severely limits the practical engineering application of self-healing materials. Therefore, developing new polymer materials that combine excellent mechanical properties with rapid repair capability under mild conditions has become an important research direction urgently requiring a breakthrough, with significant practical application value [17].

Based on the external energy source, self-healing polymers can be categorized into photoinitiated, thermally initiated, etc. Photoinitiated systems exploit light's remote, localized control for precise, energy-efficient repair, making them widely studied [18-20]. Different initiation methods offer options for various applications, expanding design possibilities. Optimizing photothermal self-healing coatings hinges on careful selection and integration of photothermal materials. Current research introduces photothermal conversion agents like graphene, carbon nanotubes, MXenes, polydopamine, and Fe_3O_4 nanoparticles into coatings, enabling self-healing under NIR irradiation. The content, dispersion stability, and interfacial interaction with the polymer matrix directly affect photothermal conversion and healing efficiency [10].

2.1.Carbon-Based Materials

Graphene and carbon nanotubes, as typical carbon nanomaterials, demonstrate significant application value in the field of functional coatings due to their excellent light absorption capacity, high thermal conductivity, large specific surface area, and outstanding mechanical properties. Incorporating them into organic coating systems not only enables rapid and precise repair of damaged areas through the photothermal conversion effect but also significantly enhances the comprehensive corrosion resistance of the coating through their physical barrier effect and electrochemical activity [21]. Cai et al. successfully developed nanocomposites with rapid photothermal responsive self-healing capability, excellent mechanical properties, and efficient recyclability by integrating reversible DA covalent bonds with graphene into an epoxy resin system. In this system, graphene not only acts as a photothermal conversion medium significantly accelerating the repair process but also functions to enhance mechanical properties [22]. Li et al. explored the use of carbon nanotubes (MWCNT) for photothermal conversion to trigger the DA thermal reversible reaction in epoxy resin, analyzing the effects of carbon nanotube content (mass fraction 0.2%~2%), the distance from the near-infrared light source to the sample, and laser power intensity on the repair effectiveness, achieving local high-precision and high-efficiency repair while showing no significant impact on undamaged areas [23].

2.2.MXene Materials

MXenes are a class of two-dimensional inorganic compounds comprising atomically thin layers of transition metal carbides, nitrides, or carbonitrides. They exhibit strong absorption of light and microwaves. Surface hydroxyl or terminal oxygen groups contribute to their metallic conductivity [24]. MXenes' excellent photothermal conversion promotes polymer chain mobility and hydrogen bond reorganization, enhancing self-healing performance. Wang et al. prepared MXene with strong photothermal conversion via etching/exfoliation and fabricated PU and MXene/PU coatings. Scratched MXene/PU coatings healed faster under 808 nm laser irradiation, attributed to MXene's layered structure extending the diffusion path for corrosive media, allowing ongoing crack repair and slowing penetration [25]. Fang et al. found that the corrosion resistance of MXene-composite coatings depends on MXene-polymer interactions and MXene's spatial distribution. Surface functionalization and compositing improve interfacial adhesion, dispersion, and compatibility. Flow-induced or electrophoretic deposition can align MXene, enhancing its barrier effect against corrosive ions [26].

2.3.Organic Materials

Common organic photothermal fillers include Aniline Black (AB), which exhibits good light absorption capacity within both the visible and near-infrared light ranges. Fang et al. adjusted the ratio of monoamine and diamine curing agents, gradually replacing the diamine m-xylylenediamine (MXDA) with the monoamine 4-(heptadecafluorooctyl) aniline (HFOA). This reduction in the epoxy network's glass transition temperature (Tg) and cross-linking density enabled thermal-induced repair above the Tg temperature, based on crack closure and molecular chain diffusion/re-entanglement mechanisms. Subsequently, Aniline Black (AB) was introduced as a photothermal conversion compound. Utilizing the indirectly generated

heat, repair under focused sunlight (with an optical density of 0.7~0.9 W/cm²) was achieved [27].

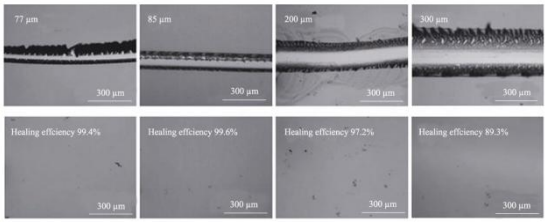

Fig.2. Morphology of Aniline Black coatings with different scratch widths after 10 min sunlight irradiation

2.4.Nanomaterials

Nano-Fe_3O_4 particles offer advantages such as low cost, ease of preparation, and good photothermal conversion performance, making them commonly used nanomaterials for photothermal self-healing [28-30]. Chen et al. prepared Diels-Alder thermally reversible self-healing polyurethane materials modified with nano-Fe_3O_4. An appropriate amount of Fe_3O_4 nanoparticles (optimal mass fraction 0.3%) can significantly enhance the mechanical properties of the material. The incorporation of Fe_3O_4 not only improved the thermal healing efficiency of the material but also endowed it with near-infrared light-responsive self-healing capability. Compared with traditional thermal healing, near-infrared light-triggered healing demonstrated faster speed and higher efficiency, with the material maintaining excellent repeatable healing performance. After three damage-healing cycles, it still retained a healing efficiency of 55.34% [31].

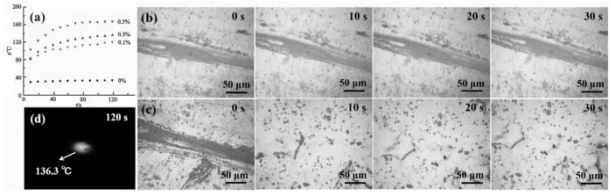

Fig.3.(a) Temperature changes of PU-DA-Fe3O4 with different mass fractions of Fe3O4 nanoparticles exposed to 808 nm NIR; POM images of cracks in (b) PU-DA and (c)PU-DA- Fe3O4 films upon exposed to 808 nm NIR; (d) thermal image of PU-DA- Fe3O4 (0.3%) exposed to 808 nm NIR

3.Applications and Future Outlook

3.1.Application Areas

Photothermal self-healing coatings, with their unique remote, localized, controllable repair, are transitioning from lab research to targeted engineering applications. Their core value lies in enabling in-situ repair of hard-to-access or sensitive components, enhancing service reliability and lifespan [32]. Key application prospects include:

Aerospace: Aircraft skins, composites, and engine components are prone to micro-cracks from vibration, fatigue, or impact. Applying these coatings allows rapid crack repair under NIR light during maintenance, preventing damage propagation, extending inspection intervals, and improving safety [33].

Marine Anticorrosion: Ships, offshore platforms, and pipelines face harsh, corrosive seawater environments. Traditional coatings, once scratched, allow rapid corrosion spread. Photothermal self-healing coatings on these structures enable localized NIR irradiation after damage, triggering healing agent release or resin flow/re-fusion to 'heal' scratches, restore barrier function, and provide long-term substrate protection [34].

3.2.Future Prospects & Challenges

Despite their potential, photothermal self-healing coatings face several scientific and technical challenges. Future research should focus on:

Performance Balance & Optimization: Most systems still struggle to combine high strength/toughness with fast, efficient healing. Future designs need deeper understanding of dynamic chemistry and photothermal filler synergies. Multi-network structures and multi-mechanism approaches should optimize the balance between mechanics and healing kinetics at molecular/nano scales.

Intelligent & Precise Photothermal Systems: Next-generation coatings should become smarter, incorporating multi-stimuli responsiveness for complex environments. Self-feedback/regulating systems, e.g., using indicators for visual monitoring or feedback-controlled healing agent release, could enable deeper damage repair.

Long-Term Durability & Environmental Adaptability: Coatings serve for years/decades, requiring evaluation of long-term photothermal stability, aging resistance, and retained healing ability under real conditions.

Long-term reliability data is crucial for engineering adoption.

Scalable Fabrication & Cost-Effectiveness: High-performing fillers and complex syntheses are often expensive, hindering large-scale use. Developing low-cost, green synthesis/compositing methods and scalable application techniques is necessary for widespread use.

Looking forward, interdisciplinary convergence of materials science, chemistry, optics, and AI may help overcome current bottlenecks, evolving photothermal self-healing coatings into truly intelligent material systems capable of sensing damage, deciding on, and executing repair, offering revolutionary solutions for long-life, safe operation of critical engineering assets and sustainable development.

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Common Challenges and Overcoming Ways Faced by Ideological and Political Education in Chinese and Russian Universities

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KEYWORDS

Youth development research;

Applied educational technology;

Sino Russian education cooperation;

Cross cultural education research;

ABSTRACT

In the context of globalization, the rapid development of Internet technology and the transformation of the consciousness of the young generation, it has become a common important task for China and Russia to effectively cultivate the moral character and patriotism of students. Despite their different histories and political systems, universities in both countries face similar challenges: external influences of different ideologies, disorderly information spaces on the internet, and the need to adjust educational content to meet the needs of the new generation of students. This article provides a detailed analysis of these three key common issues and studies and compares solutions from China and Russia. Through comparative analysis, effective strategies can be identified to help better cultivate a generation of young people who are loyal to the country and responsible.

In the context of increasing globalization and digitization in the 21st century, higher education shoulders the key mission of cultivating the national identity, social responsibility, and global capabilities of the younger generation. As major civilized countries that influence the international structure, China and Russia face common historical tasks and development issues in the formation of student value orientations. This article uses comparative research and systematic analysis methods to explore in depth the four major challenges faced by the education systems of the two countries in the field of value education: the pressure of value dialogue under global cultural interaction conditions. The need for value integration during the period of social transformation, the crisis of matching traditional education models with the characteristics of the new generation of students, and the structural adjustment of the education ecosystem under the influence of digitalization. This study suggests that these challenges have profound common roots, rooted in the conflict between traditional educational paradigms and modern tensions. On this basis, a four-dimensional response model was constructed, which includes strategic support, practical innovation, technology integration, and international cooperation. Proposed ways to systematically improve the quality of value orientation formation by strengthening the national education management system, transforming teaching paradigms, creating an intelligent education ecosystem, and deepening strategic cooperation in the education field between China and Russia. The theoretical contribution of this study lies in providing a comprehensive analytical foundation for comparing the education systems of China and Russia, while its practical value lies in providing effective recommendations for decision-makers in the field of education. At the same time, this provision provides important guidance for the global practice of forming values in the context of cultural diversity.

ВВЕДЕНИЕ

Образование выполняет не только функцию передачи знаний, но и, что более важно, задачу формирования личности. Помощь студентам в выработке правильных ценностных ориентиров, взглядов на мир и жизнь,

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воспитание у них гражданской ответственности и преданности своей стране составляет важнейшую часть образовательного процесса. В Китае эта деятельность определяется как «идейно-политическое воспитание». В России, при возможных терминологических различиях, также придается большое значение «патриотическому воспитанию» и «духовно-нравственному воспитанию» студенческой молодежи.

Будучи крупными мировыми державами с уникальным и богатым историко-культурным наследием, Китай и Россия за последнее столетие прошли через значительные социальные преобразования, сформировав собственные образовательные системы. В современную эпоху углубляющейся глобализации и увеличения скорости распространения информации благодаря интернету воспитательная работа в университетах обеих стран столкнулась с новыми, беспрецедентными вызовами.

Каковы эти вызовы? Каким образом две страны реагируют на них? Поиск ответов на эти вопросы представляет интерес не только для педагогов, но и для всех, кого волнует будущее своего государства. Таким образом, данная статья фокусируется на анализе общих проблем в сфере идеологического и политического воспитания в университетах Китая и России и подробно рассматривает стратегии их преодоления, что может послужить основой для продуктивных размышлений.

Учреждения высшего образования как оплоты создания знаний и подготовки кадров напрямую определяют будущую конкурентоспособность страны и преемственность цивилизации. Среди многомерных целей высшего образования формирование характера студентов, их ценностей и ориентаций всегда занимает центральное место, что связано со способностью молодежи сформировать целостное мировоззрение, взгляд на жизнь и систему ценностей, стать ответственными гражданами общества. Для Китая и России, находящихся на ключевом этапе национального возрождения, эффективная реализация задач по формированию ценностных ориентаций в вузах имеет стратегическое значение, выходящее за рамки обычной образовательной деятельности. Китайская образовательная система определяет «воспитание добродетели и талантов» как фундаментальную задача, стремясь построить систему всестороннего образования, интегрирующую интеллектуальное, физическое, эстетическое и трудовое развитие, и пронизывать весь процесс обучения и воспитания формированием основных социалистических ценностей. Российская образовательная система, пройдя через период поисков в эпоху социальной трансформации, вновь утвердила приоритет патриотического и духовно-нравственного воспитания в государственной стратегии. Через такие политические рамки, как «Национальный проект "Образование" на период до 2025 года», Россия системно продвигает переориентацию ценностей в национальной образовательной системе, направленную на воспитание у молодого поколения национальной гордости, исторической преемственности и гражданской ответственности.

1.Общие Проблемы Формирования Ценностных Ориентаций Студентов в Вузах Китая и России

Путем углубленного изучения систем формирования ценностных ориентаций в вузах Китая и России общие проблемы можно свести к комплексной диагностической структуре, состоящей из четырех измерений: внешняя среда, социальные изменения, модель образования и технологическая экосистема. Эти измерения взаимосвязаны, усиливают друг друга и образуют комплекс проблем, требующих системного подхода.

1.1.Измерение Внешней Среды:Культурный Диалог и Ценностная Адаптация в Контексте Глобализации

В современных условиях углубляющейся глобализации границы образовательных систем национальных государств становятся все более проницаемыми, транснациональные потоки идей и культуры достигают беспрецедентных масштабов и интенсивности. Эта открытость, создавая возможности для развития, одновременно подвергает системы формирования ценностных ориентаций двух стран сложной и разнообразной внешней культурной среде, создавая постоянное давление ценностного диалога и проблемы культурной адаптации.

1.1.1.Нормализация межкультурной передачи ценностей и развитие способности реагирования местных образовательных систем

Развитые страны, используя свои преимущества первопроходцев в процессе модернизации и глобальное влияние культурной индустрии, через международное академическое сотрудничество, транснациональные медиасети, продукты массовой культуры (такие как голливудские фильмы, поп-музыка, контент социальных сетей) и различные проекты неправительственных организаций, продолжают транслировать определенные ценностные установки и образы жизни молодежи Китая и России. Эти установки, как правило, характеризуются индивидуализмом, либерализмом, потребительством и универсализмом, и, обогащая культурный опыт молодежи, предоставляя многоосновные ориентиры, одновременно создают глубокое давление для диалога и необходимость адаптации для популярных систем ценностей двух стран, основанных на коллективизме, социальной ответственности, национальной идентичности и традиционной культуре. Как образовательным системам направлять студентов в открытом контексте к рациональному культурному различению, критическому мышлению и самостоятельному ценностному строительству, формируя культурную уверенность и ценностную устойчивость, не впадая ни в закрытость и отторжение, ни в слепое подражание, стало общей задачей времени для педагогов двух стран. Этот процесс затрагивает сложные механизмы культурной психологии, включая формирование культурной идентичности, корректировку ценностных приоритетов и развитие навыков межкультурной коммуникации, что требует от образовательной системной инновации в содержании, методах и создании среды.

1.1.2.Асимметрия международного информационного порядка и оптимизация стратегий формирования национальной идентичности молодежи

Существующая глобальная структура распространения информации по-прежнему демонстрирует значительный структурный дисбаланс, при котором определенные нарративные перспективы, укорененные в конкретных культурных традициях, часто доминируют в международном информационном поле. Эта несбалансированность часто приводит к фрагментарному, выборочному или даже искаженному представлению и интерпретации уникальных путей развития, исторического вклада, культурных особенностей и внутренней политики Китая и России. Студенчество, являясь наиболее активными цифровыми аборигенами и восприимчивыми получателями международной информации, при отсутствии системного медиаобразования, фундаментального исторического образования и тренировки критического мышления, легко подвержены влиянию этой неполной информационной экосистемы, формируя фрагментированное или даже искаженное восприятие собственного пути развития и международного положения, что потенциально препятствует формированию прочной национальной идентичности и здорового национального самосознания. Образовательным системам необходимо повышать способность формулировать повестку и инновации в дискурсе в сфере международных коммуникаций, путем разработки качественного многоязычного образовательного контента, поощрения ученых к выходу на международную арену, поддержки участия студентов в глобальном диалоге, активно формировать объективную и доброжелательную международную медиасреду.

1.2.Измерение социальных изменений: интеграция ценностей и историческая преемственность в переходный период

Китай и Россия находятся на углубляющейся стадии перехода от традиционного к современному обществу, изменения внутренней социальной структуры, плюрализация интересов и раскрепощение идей совместно формируют динамичную социальную среду, с которой должно справляться формирование ценностных ориентаций.

2.Пути совместного развития для преодоления общих проблем: системное решение

Перед лицом вышеупомянутых многомерных и переплетенных комплексных проблем Китаю и России

необходимо, стоя на стратегической высоте построения сообщества с единой судьбой человечества, продвигать глубокую, системную смену парадигмы и совместные инновации в формировании ценностных ориентаций в вузах, превращая проблемы в историческую возможность скачкообразного развития.

2.1.Уровень государственной стратегии: усиление проектирования, ресурсного обеспечения и системной интеграции

Формирование ценностных ориентаций как стратегический проект, касающийся долгосрочной стабильности и цивилизационной преемственности страны, должен быть включен в проектирование национального развития, получать постоянное политическое внимание, четкие стратегические указания и надежное ресурсное обеспечение.

2.1.1.Совершенствование системы образовательной политики и среды правовых гарантий

Две страны должны стремиться к созданию более совершенной, скоординированной системы законов и нормативных актов о национальном образовании и долгосрочных национальных планов развития образования, уточняя центральное положение формирования ценностных ориентаций в целях подготовки кадров высшего образования, основные концепции, стандарты содержания и требования к качеству. Путем разработки научных конкретных планов реализации, профессиональных стандартов сертификации преподавателей, стабильных механизмов финансовых вложений, многосторонней системы мониторинга и оценки качества образования, создать для базовой образовательной практики основанную на верховенстве права, стандартизированную, предсказуемую политическую среду и институциональную поддержку, гарантировать правильное направление развития образовательного дела и способность к устойчивому развитию.

2.1.2.Укрепление системы ответственности вузов как основных субъектов воспитания и эффективности управления

Университеты как передовой рубеж формирования ценностных ориентаций, их руководство и академические лидеры должны добросовестно выполнять основную ответственность за воспитание, глубоко интегрируя концепции и требования формирования ценностных ориентаций во весь процесс и все аспекты позиционирования вуза, стратегии развития, планирования дисциплин, строительства специальностей, кампусной культуры и системы управления. Создать и совершенствовать охватывающие все поля воспитания (аудиторные занятия, академические мероприятия, студенческие организации, сетевые платформы) нормативы управления и рабочие процессы, сформировать эффективные внутренние механизмы гарантии качества, обеспечить ясность и здоровье образовательной среды и всестороннюю реализацию воспитательной ориентации.

2.2.Уровень образовательной практики: углубление инноваций в содержании, реформ методов и расширения возможностей преподавателей

Фундаментальная жизненная сила образования заключается в идейной истинности его содержания, эмоциональной привлекательности формы и научной эффективности методов. Необходимо идти в ногу со временем, отвечать на запросы студентов, осуществлять постоянную реконструкцию системы содержания и революцию в методологии преподавания.

2.2.1.Содействие модернизации системы содержания образования и инновациям в дискурсе

Путь инноваций в китайском контексте: Следует придерживаться сочетания основных принципов марксизма с конкретной реальностью Китая и традиционной китайской культурой, постоянно продвигать теоретические инновации и руководствоваться ими в образовательной практике. Необходимо умело превращать исторические достижения и преобразования в национальном развитии в живые, глубокие, убедительные учебные ресурсы.

Одновременно углублять творческое преобразование и инновационное развитие excellent традиционной китайской культуры, системно разъяснять ее современную ценность: человеколюбие, народ как основа, честность, справедливость, гармония, стремление к великому единению, и соединять ее с революционной культурой, передовой социалистической культурой, а также всеми лучшими достижениями человеческой цивилизации, построить систему содержания и дискурса формирования ценностных ориентаций с китайской спецификой, отражающую дух времени, богатую интеллектуальным обаянием.

Направление поисков в российском контексте: Можно продолжать углубленно изучать свои обширные и глубокие историко-культурные ресурсы, стремиться построить связную, уверенную, открытую систему национального исторического нарратива и культурной идентичности. Активно демонстрировать ее выдающийся вклад в литературу, искусство, философию, науку и технику, а также проявленные на разных исторических этапах национальную пластичность, патриотический энтузиазм и инновационную энергию.

2.2.2.Осуществление смены парадигмы методологии преподавания и расширение возможностей за счет технологий

От «передачи знаний» к «формированию ценностей»: Повсеместно внедрять ориентированные на студента исследовательское обучение (Research-based Learning), обучение на основе проблем (Problem-based Learning), ситуационное моделирование (Simulation), тематические семинары (Seminar) и другие интерактивные, исследовательские методы обучения. Сосредоточить усилия на создании открытой, инклюзивной, равноправной среды аудиторного диалога, поощрять студентов к активному исследованию, совместному обучению, критическому мышлению и рациональному выражению, направлять их в разрешении ценностно-познавательных конфликтов, в столкновении идей формировать консенсус, в конечном итоге завершать самостоятельное построение и внутреннее принятие ценностей.

Реализация системного проекта профессионального развития преподавательского состава: Создать и усовершенствовать стратифицированные и классифицированные центры развития преподавателей и механизмы регулярного обучения, через регулярные тематические курсы повышения квалификации, высокоуровневые академические мастерские, международные академические обмены, стажировки на передовой, конкурсы педагогического мастерства, распространение выдающихся результатов преподавания и другие пути, всесторонне повышать теоретическую глубину, педагогическое искусство, технологическую грамотность, исследовательские способности и личностное обаяние преподавателей. Улучшить механизм «наставничества», создать междисциплинарные, межуниверситетские сообщества педагогических инноваций. Одновременно расширять источники качественных кадров, привлекать руководителей государственных органов, экспертов в области общественных наук, передовиков производства, предпринимателей и отраслевых лидеров с богатым практическим опытом в качестве приглашенных профессоров или внештатных наставников, сформировать высококвалифицированную, профессиональную, полную силу и творчества команду воспитателей.

2.3.Уровень технологической интеграции: построение новой интеллектуальной образовательной экосистемы, объединяющей онлайн и офлайн

Цифровое пространство превратилось из «вспомогательного инструмента» образования в его «базовую среду». Необходимо придерживаться концепции «технологии расширяют возможности образования», активно планировать, превращая киберпространство в стратегический оплот инновационного развития формирования ценностных ориентаций.

2.3.1.Повышение цифрового лидерства образовательных субъектов и способности управления сетевым пространством

Проводить системное обучение цифровой грамотности и навыкам применения новых медиа для широкого круга преподавателей, кураторов и управленцев. Поощрять и поддерживать их активную интеграцию в студенческие сетевые сообщества, умело использовать язык сети для равноправного, искреннего, эффективного диалога со

студентами, своевременно реагировать на сетевые запросы, точно направлять сетевые эмоции, эффективно направлять сетевое общественное мнение, стремиться стать «лидерами мнений», «духовными наставниками» и «близкими друзьями» в сетевой жизни студентов.

2.3.2.Полное включение сетевой грамотности и образования цифровых граждан в систему основных курсов общего образования

Ввести для всех студентов обязательные или основные общеобразовательные курсы по сетевой грамотности, медиакритике, информационной этике, ответственности цифровых граждан, системно развивать у студентов способность различать информацию, критическое мышление, осознание безопасности данных, представление о верховенстве права в сети и чувство цифровой социальной ответственности. Направлять их к цивилизованному использованию сети, рациональному выражению, законному пребыванию в сети, сознательно противодействовать сетевые слухи и вредную информацию, активно создавать и распространять позитивную энергию в сети, стать стойкими защитниками и активными строителями ясного киберпространства.

Заключение

Проведенный сравнительный анализ позволяет сделать следующие выводы и наметить возможные перспективы.
Во-первых, природа вызовов, с которыми столкнулись Китай и Россия, является глобальной и отражает общие тенденции эпохи, связанные с информационной открытостью, цифровизацией и сменой ценностных парадигм. Это означает, что идеологическое и политическое воспитание не может оставаться в прежних формах; оно должно быть динамичным, готовым к постоянным трансформациям и перманентному обновлению своих методов и содержания.
Во-вторых,, и это, пожалуй, самый важный вывод, конечный успех будет определяться не столько совершенством административных механизмов, сколько способностью воспитания завоевать не только умы, но и сердца молодежи. Любые, даже самые прогрессивные инновации останутся неэффективными, если они не находят глубокого отклика во внутреннем мире студентов, не отвечают на их экзистенциальные запросы, не помогают в решении жизненных проблем и не связывают идею служения стране с возможностью реализации личного потенциала. Будущее воспитания видится в искреннем диалоге, уважении к личности студента и гармоничном сочетании национальных стратегических интересов с личными устремлениями и мечтами молодых людей.
Для Китая и России работа по воспитанию молодежи продолжает оставаться актуальной и развивающейся задачей, от которой во многом зависит будущий путь развития. Взаимный обмен успешным опытом и извлеченными уроками, несомненно, имеет большую практическую ценность и может обогатить арсенал педагогических средств обеих сторон. Успех на этом пути важен не только для будущего двух стран, но и для формирования стабильного и ответственного поколения в глобальном масштабе. Есть основания надеяться, что благодаря последовательным и взвешенным усилиям обе нации смогут выработать эффективные и аутентичные модели для подготовки молодого поколения, сочетающего широкий международный кругозор с искренней любовью и ответственностью перед своим Отечеством.

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Общие Вызовы и Пути Их Преодоления в Сфере Идеологического и Политического Воспитания в Университетах Китая и России

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Аннотация:В условиях глобализации, стремительного развития интернет-технологий и трансформации сознания молодого поколения эффективное формирование у студентов морально-нравственных качеств и патриотизма стало общей важной задачей для Китая и России. Несмотря на различия в истории и политических системах, университеты обеих стран сталкиваются со схожими проблемами: влияние извне различных идеологий, неупорядоченность информационного пространства в сети, а также необходимость адаптации содержания образования к запросам нового поколения учащихся. В данной статье подробно анализируются эти три ключевые общие проблемы, а также исследуются и сравниваются подходы к их решению, применяемые в Китае и России. Проведенный сравнительный анализ позволяет выявить эффективные стратегии, которые могут способствовать совершенствованию работы по воспитанию молодого поколения, преданного своей стране и осознающего гражданскую ответственность.

В условиях углубляющейся глобализации и цифровизации в XXI веке высшее образование несет ключевую миссию по формированию у молодого поколения национальной идентичности, социальной ответственности и глобальной компетентности. Как крупные цивилизационные государства, оказывающие формирующее влияние на международную структуру, Китай и Россия сталкиваются с исторически общими задачами и проблемами развития в сфере формирования ценностных ориентаций студентов. В данной статье с использованием методов сравнительного

исследования и системного анализа глубоко исследуются четыре ключевых вызова, с которыми сталкиваются образовательные системы двух стран в сфере ценностного воспитания: давление ценностного диалога в условиях глобального культурного взаимодействия, потребность в интеграции ценностей в период социальной трансформации, кризис соответствия традиционных моделей образования характеристикам нового поколения обучающихся и структурная перестройка образовательной экосистемы под влиянием цифровых технологий. Исследование показывает, что эти вызовы имеют глубокое общее происхождение, коренящееся в столкновении традиционных образовательных парадигм и напряжений современности. На этой основе строится четырехмерная модель реагирования, включающая стратегическую поддержку, практические инновации, технологическую интеграцию и международное сотрудничество. Предлагаются пути системного повышения качества формирования ценностных ориентаций через усиление национальных систем управления образованием, трансформацию педагогических парадигм, создание интеллектуальной образовательной экосистемы и углубление стратегического сотрудничества Китая и России в сфере образования. Теоретический вклад исследования заключается в создании комплексной аналитической основы для сравнения систем образования Китая и России, а практическая ценность — в предоставлении лицам, принимающим решения в сфере образования, действенных рекомендаций. Одновременно статья служит важным ориентиром для глобальной практики формирования ценностей в условиях культурного многообразия.

Ключевые слова:исследование молодежного развития; применение образовательных технологий; российско-китайское образовательное сотрудничество; межкультурные образовательные исследования;

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A Study on the Effective Implementation of Humanities Education in Higher Vocational Colleges

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KEYWORDS

Higher vocational colleges;

Humanistic quality education;

Methodology

ABSTRACT

In the new era, vocational college students face issues such as insufficient humanistic knowledge, weak humanistic abilities, and low levels of humanistic spirit. The main reasons for these problems lie in the fact that vocational education places more emphasis on professional knowledge and skills while misinterpreting the goal of talent cultivation. There is a misunderstanding regarding the proper relationship between humanistic qualities and employment, and the relationship between humanistic quality education courses and specialized education courses has not been well aligned. Vocational colleges in the new era should gather various forces and resources to better meet students' growth needs, adapt to the demands of economic and social development, and achieve the development goals of vocational education in the new era.

INTRODUCTION

Humanistic quality refers to the personal qualities formed by knowledge, concepts, abilities, emotions, and other aspects. It is an internal manifestation of knowledge and skills, as well as external expressions such as patriotic ideals. Humanistic quality is crucial for every student, directly impacting their personal development after entering society. In light of this, vocational colleges have increasingly emphasized the cultivation of students' humanistic qualities in recent years. However, due to their late start, they still need to conduct in-depth research on effective implementation strategies

1.The Present Situation of Humanistic Quality Education In Higher Vocational Colleges

The education evaluation system needs improvement. With the promotion of quality-oriented education, humanistic quality education has gradually gained attention. Although higher vocational colleges started their humanistic quality education programs relatively late, they have developed rapidly and have already achieved certain experiences and results. Some higher vocational colleges have even integrated humanistic quality education into their talent cultivation plans, forming unique educational characteristics. However, in the current thriving development of humanistic quality education in higher vocational colleges, most institutions lack systematic implementation plans and comprehensive evaluation systems for humanistic quality education. This, to some extent, hinders the effective conduct of humanistic quality education.

The curriculum for humanities needs to be expanded. From the course settings of vocational colleges in our country, it is evident that institutions focus on meeting market development needs, with more emphasis on disciplines where there is a significant talent gap in enterprises. The course content primarily centers around professional knowledge, supplemented by practical skills and operational techniques. Teachers concentrate on professional education and the teaching objectives of cultivating students' professional knowledge and skills, leading to a lack of humanistic quality education in vocational colleges. Even though some vocational colleges have added courses in humanistic qualities, there is still a gap between the course content and class hour arrangements and the goals of

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achieving humanistic quality education.

Students' humanistic literacy needs improvement. After the expansion of higher vocational education, the overall student body structure has undergone significant changes, with varying quality among students. In terms of humanistic qualities, this manifests as a narrower scope of humanistic knowledge and lower levels of humanistic literacy. The reasons for this phenomenon are twofold: firstly, the learning foundation of students before entering higher vocational colleges is relatively weak; secondly, higher vocational institutions only offer conventional courses in ideological and political education, Chinese language, and writing, which leads to knowledge gaps in areas such as art, history, geography, and philosophy, resulting in an insufficient breadth of humanistic knowledge.

2.Analysis of The Causes of Problems In Humanistic Quality Education For Students In Higher Vocational Colleges

The concept of humanistic quality education is lacking. For vocational colleges, the focus is on training students' practical skills, leading to a strong utilitarian mindset throughout the school. The humanistic atmosphere is weak, and the concept of humanistic quality education is absent. Vocational colleges have become mere preparatory and training institutions for careers, losing their important function of nurturing individuals and neglecting to explain the reasons and principles behind why students should live.

The humanities and quality education curriculum system needs further optimization. The cultivation of students 'humanistic qualities is mainly implemented through course instruction. Vocational colleges should adjust the course structure and teaching content, increase the proportion of humanities courses, enrich elective courses in literature, social sciences, and arts, solidify students' foundational knowledge in humanism, and add courses related to ethics, morality, and artistic appreciation to reverse the educational tendency of "emphasizing majors over humanities" in vocational colleges. However, there are too few courses that embody humanistic spirit. The course opening rates for ideological and political education courses such as "An Overview of Mao Zedong Thought and the Theoretical System of Socialism with Chinese Characteristics," "Ideological and Moral Cultivation," and "Forms and Policies" are all 100%; the course opening rate for "Employment Guidance," which is closely related to student employment, is also 100%; and the course opening rate for "Physical Education," which is closely related to students' physical health, is 100%. These courses have relatively sufficient average class hours, indicating that the cultivation of relevant knowledge and skills for vocational students can be basically guaranteed. Additionally, although the course opening rates for "Literary Appreciation" and "Music Appreciation" reach 100%, the class hours are severely insufficient, making it difficult to achieve effective teaching; while "Applied Writing," "Mental Health," and "Modern Etiquette" are required courses, their opening rates are very low, being offered only in the "Human Resource Management" program across the entire school, highlighting the insufficient emphasis on humanistic quality education in vocational colleges

course title	Enrollment rate (%)	Average class hours
An overview of MAO Zedong Thought and the theoretical system of socialism with Chinese characteristics	100	28
Ideological and moral cultivation	100	36
Form and policy	100	20
Career development and employment guidance	100	20
physical culture	100	84
literary appreciation	100	18
Music appreciation	100	18
Applied writing	25	30
mental health	25	30
Modern etiquette	5	30

Table.1. Offerings of humanities courses in the four departments

Humanistic quality education resources are severely insufficient. In the current situation of higher vocational colleges, there is a widespread lack of emphasis on humanistic quality education. The focus of faculty development tends to be on cultivating "dual-qualified" teachers, leaving fewer opportunities for humanistic teachers in their professional growth. They generally receive little attention and often operate outside the mainstream teaching framework. There is also a significant lack of concern, support, and assistance for humanities teachers, all of which greatly impact the implementation of humanistic quality education among students at higher vocational colleges.

3.Effective Ways To Implement Humanistic Quality Education In Higher Vocational Colleges

Constructing a platform system for humanities quality education. To enhance the humanistic qualities of vocational college students, apart from objectively improving the curriculum and strengthening the faculty, it is more crucial to boost students 'subjective awareness and fully mobilize their initiative. On one hand, create a favorable learning environment for students in their careers; on the other hand, build platforms for hands-on learning, enabling students to truly engage, learn by doing, and do while learning. This not only enhances professional skills but also integrates humanities quality education, thereby continuously improving students' overall qualities.

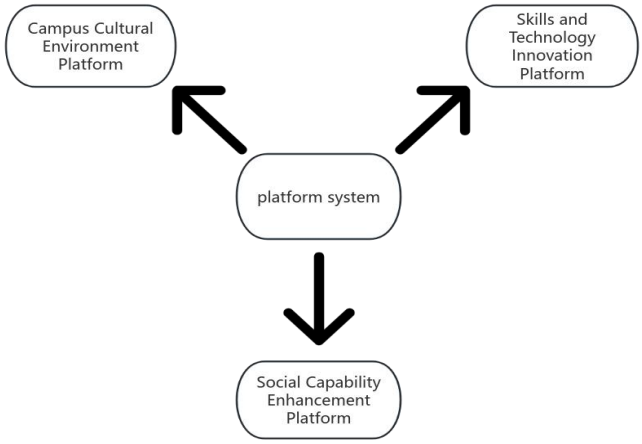

Fig.1. Platform system

Constructing a Humanistic Quality Education Curriculum System. The construction of humanistic quality courses in higher vocational colleges should adhere to the orientation of fully integrating humanistic quality education, with the aim of cultivating students' excellent moral sentiments, humanistic spirit, and character mindset, guiding them to establish correct "three views." Therefore, the curriculum design should reflect the characteristics of lifelong education and lifelong learning, with the ultimate goal of nurturing highly skilled professionals who develop comprehensively.

First, it is essential to organically integrate professional skills education with vocational humanities education. Integrating humanities education into professional skills training helps vocational college students understand the world and grasp its essence while pursuing truth and valuing values. Through curriculum design, we can stimulate students' sense of agency, assist them in refining their knowledge structure, enhancing their capabilities, and fostering them into well-rounded, highly skilled professionals.

Secondly, the characteristics of vocational education should be highlighted, with course content closely linked to society, industries, and service recipients. Cultural quality education courses in higher vocational colleges should help students develop noble professional ethics, correct career values, and positive attitudes towards their careers. Modern enterprises do not lack skilled operators; what they need more are well-rounded employees who are of high moral character, have a positive attitude, and strong service awareness.

Conclusion

In order to promote the all-round development of students, it is urgent for higher vocational colleges to update their educational concepts. Only by integrating humanistic education into vocational education and striving to create a good environment for humanistic quality education can higher vocational colleges develop healthily in the long term and enable higher vocational students to grow up healthily and find jobs.

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Research On The Complementarity Between Economic Activities And Teaching Activities In Educational Institutions

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KEYWORDS

Educational institutions;
Economic activities;
Teaching activities;
Complementarity;
Educational management;
Resource allocation

ABSTRACT

The coordinated development of education and economy is a core issue in macro social progress, while the complementarity between economic and teaching activities within educational institutions constitutes a key proposition in micro management. Adopting a mixed-methods research approach that integrates systematic literature review, case study, and SWOT analysis, this paper takes Chinese educational institutions as the specific research object to systematically explore the theoretical connotation, practical manifestations, and influencing mechanisms of their complementarity. The study finds that the principle of complementarity can realize the synergistic optimization of resource allocation and talent training goals in educational institutions: economic activities provide stable resource support for teaching practice, and teaching achievements in turn feed back economic resources through reputation accumulation and social value transformation. Five optimization strategies are proposed: establishing a "teaching-oriented" financial philosophy, constructing an inter-departmental coordination mechanism, applying digital management tools, deepening the integration of production, education, and research, and improving a full-process supervision and feedback system. This research not only enriches the application dimension of complementarity theory in the field of educational management but also provides operable paths for educational institutions to improve management efficiency and achieve a win-win situation between educational quality and economic benefits.

INTRODUCTION

1.1.Research Background

Since the 21st century, the in-depth integration of education and economy has become a global consensus. At the macro level, education drives economic growth through human capital accumulation, and economic strength provides material guarantee for educational investment [1]. At the micro level, educational institutions such as schools and universities have dual attributes of "talent training" and "resource management", and need to find a balance between teaching goals and economic efficiency. In practice, two typical contradictions have emerged: some institutions overemphasize teaching while neglecting cost control, leading to capital chain breakage or resource waste; others fall into the "commercialization trap", compressing teaching investment with profit maximization as the goal and eroding the essence of education [2]. Therefore, clarifying the complementary relationship between economic activities and teaching activities has become a core breakthrough to solve the dilemma of educational management and achieve high-quality development.

1.2.Research Objectives and Significance

Research objectives: To clarify the theoretical logic of the complementarity between economic and teaching activities in educational institutions, analyze its specific manifestations and restricting factors in practice, and propose optimization strategies suitable for the Chinese

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educational context.

Theoretical significance: Introducing the "complementarity" theory from the field of physics into educational management research, constructing an analytical framework of "resource-value" two-way transformation, and filling the gap of "more macro coordination and fewer micro mechanisms" in existing research.

Practical significance: Providing solutions for educational institutions to address practical problems such as "unbalanced resource allocation" and "departmental barriers", especially offering decision-making references for the integration of production and education in vocational colleges and application-oriented universities.

1.3.Research Methods

Systematic literature review: Retrieving studies related to "education-economy complementarity" and "educational resource allocation" from databases such as CNKI and Web of Science (2010-2025), a total of 30 literatures were analyzed to sort out the theoretical context and research gaps.

Case study method: Selecting 3 typical Chinese educational institutions (public universities, vocational colleges, and private middle schools), extracting complementary practical models through interviews and reports (covering 20 directors from financial and teaching departments each) and policy text analysis.

SWOT analysis: Systematically identifying the strengths, weaknesses, opportunities, and threats of Chinese educational institutions in realizing complementarity based on case data and policy environment, so as to provide a basis for strategy formulation.

2.Connotation of Complementarity and Adaptation Logic in the Educational Field

2.1.Interdisciplinary Origin of Complementarity Theory

The concept of "complementarity" originated from Niels Bohr's research on quantum mechanics, with the core meaning that different elements in a system form a synergistic effect of "1+1>2" through dynamic interaction [3]. In the field of social sciences, this theory has been expanded into two paradigms: "functional complementarity" and "resource complementarity". The former emphasizes that different activities optimize system functions through role division (such as the coordination between production and marketing in enterprises), while the latter focuses on resource exchange between elements (such as the knowledge and capital exchange in industry-university-research cooperation) [4].

2.2.Core Logic of Complementarity in Educational Institutions

Although economic activities (fundraising, budget management, cost control, etc.) and teaching activities (curriculum design, teaching implementation, quality evaluation, etc.) in educational institutions have different goals, they have three levels of complementary relationships:

Resource support level: Economic activities provide a material foundation for teaching. For example, the improvement of teachers' salaries (economic investment) can reduce the turnover rate of teachers, thereby enhancing teaching stability; the update of experimental equipment (resource allocation) can support the development of practical teaching [6].

Value feedback level: Teaching activities create value-added space for economic activities. For example, the brand reputation formed by high-quality teaching can attract special government appropriations (such as construction funds for "Double First-Class" universities) and social donations (such as corporate cooperation funds for private schools).

Goal coordination level: Both ultimately unify in "maximizing educational value". Economic activities are guided by "efficiently supporting teaching", and teaching activities are oriented towards "improving the efficiency of social value transformation", forming a closed loop of "resource input - teaching output - value transformation - re-resource input".

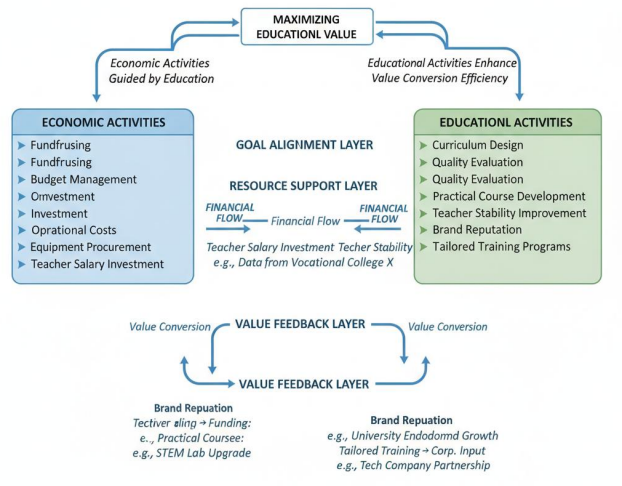

Fig.1. Economic Structure of Educational Institutions — Three-Level Logical Structure Diagram of Complementarity in Teaching Activities

3.Practical Manifestations of Complementarity between Economic and Teaching Activities in Educational Institutions

3.1.Support Paths of Economic Activities for Teaching Activities

3.1.1.The Structure of Fund Investment Affects the Gradient of Teaching Quality

Empirical research by the Learning Policy Institute in the United States shows that when educational funds are tilted towards "core teaching elements" (teacher training, small-class teaching, curriculum development), the improvement range of students' academic performance is 37% higher than that of "hardware investment" (school building construction, equipment procurement) [6]. Chinese cases have also verified this law: a vocational college allocated 60% of its funds to the training of "double-qualified" teachers (economic activity), and its award-winning rate in skill competitions increased from 15% to 48% within 3 years (teaching achievement), forming a positive cycle of "investment - quality" [2].

3.1.2.Economic Management Efficiency Ensures the Stability of Teaching Processes

Higher education is a capital-intensive field, and the level of financial management directly affects the continuity of teaching. For example, the requirement of "budget performance management" proposed in China's "Education Modernization 2035" has promoted universities to establish a linkage mechanism of "teaching needs - budget allocation". Through refined cost accounting, a public university reduced the proportion of non-teaching expenditures from 28% to 15%, and all the saved funds were used for laboratory upgrading, increasing the opening rate of practical courses by 22% [9].

3.2.Feedback Mechanisms of Teaching Activities for Economic Activities

3.2.1.Reputation Accumulation Expands Resource Channels

The "brand effect" formed by teaching quality has significant economic value: Chinese "985 Project" universities obtain an average social donation 5.2 times that of ordinary universities by virtue of high-quality teaching and scientific research achievements; a private middle school increased its annual tuition income growth rate from 8% to 23% through the improvement of college entrance examination admission rate (teaching achievement) [13].

3.2.2.Social Value Transformation Obtains Policy Dividends

The social benefits of teaching activities can be directly transformed into economic resources. For example, the "order-based training" (teaching activity) in vocational colleges meets the employment needs of enterprises, not only obtaining enterprise equipment donations (with an average value exceeding 5 million yuan per school) but also being able to apply for government "industry-education integration special subsidies" [11]; the poverty alleviation training (extended teaching activity) in universities can be included in government procurement service projects, with an average annual increase of 3 million yuan in income [14].

3.3.Complementarity Orientation in Policy Practice

Many countries have incorporated the principle of complementarity into educational reform: China's "Measures for the Administration of Vocational Education Program Settings" in 2024 clearly requires that "the budget for program construction must match industrial needs",

promoting the connection between enterprise funds and teaching resources; Russia's "Higher Education Digital Transformation Plan (2025-2030)" lists "improvement of teaching quality" and "optimization of school-running costs" as equal assessment indicators, forcing universities to achieve economic-teaching coordination [10].

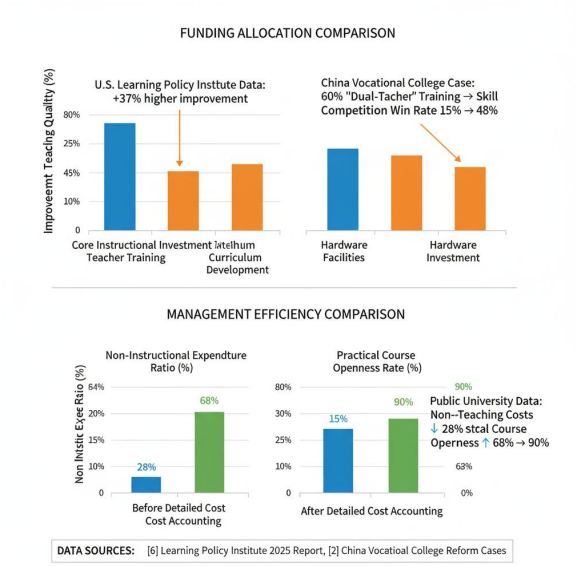

Fig.2. Bar Chart Comparing the Support Effect of Economic Activities on Teaching Activities

4.SWOT Analysis of Realizing Complementarity in Chinese Educational Institutions

4.1.Strengths

- Improved policy support system: The government has achieved "two increases" in educational funds for 10 consecutive years. In 2024, the total national educational fund investment reached 6.8 trillion yuan, of which 85% was clearly required to be used in core teaching areas [9].
- Initial formation of conceptual consensus: Case surveys show that 82% of the directors of educational institutions recognize the principle of "economy serving teaching", and 65% of universities have incorporated teaching achievements into the basis for financial budget allocation [15].
- Solid digital foundation: More than 90% of universities nationwide have built financial-teaching data sharing platforms, which can real-time monitor the correlation between resource use and teaching effects [12].

4.2.Weaknesses

- Significant inter-departmental coordination barriers: The average communication frequency between financial departments and teaching departments is only once a month, and 43% of cases have the problem of "disconnection between budget allocation and teaching needs" (for example, a university allocated 30% of its funds to administrative office, resulting in insufficient funds for practical courses) [15].
- Unbalanced resource allocation structure: The average proportion of "marketing expenditure" in private middle schools reaches 25%, far exceeding that of "teacher training expenditure" (12%); the proportion of non-teaching staff establishment in some universities exceeds 40%, occupying teaching resources [5].
- Shortcomings in management capabilities: 60% of the directors of teaching departments lack financial knowledge, and only 18% of institutions have established an inter-departmental training mechanism for "teaching - finance" [interview data].

4.3.Opportunities

- Policy dividends from industry-education integration: China's "Opinions on Deepening the Construction of a Modern Vocational Education System" proposes that "enterprises participating in school-running can enjoy tax reductions". In 2024, the funds invested by enterprises in education increased by 35% year-on-year, providing resources for economic-teaching complementarity [11].
- Empowerment of digital tools: Big data technology can realize "teaching demand prediction - dynamic budget adjustment". For example, a university optimized the allocation of laboratory resources in advance by analyzing students' course selection data, increasing equipment utilization rate by 40% [12].
- Increased participation of social resources: In 2024, the donation amount of China Education Development Foundation reached 120 billion yuan, of which 70% was designated for teaching-related projects, providing financial supplements for complementarity [14].

4.4.Threats

- Economic fluctuations impact resource supply: In 2023, the local government's educational fund budget was reduced by an average of 8%, leading some universities

to suspend the update of teaching equipment [interview data].

- Increased risk of commercialization alienation: 30% of private middle schools have the phenomenon of "reducing teaching investment to increase profits", such as reducing the class hours of experimental courses and lowering teachers' salaries [case analysis].
- High institutional coordination costs: The average approval process between educational departments and financial departments takes 2 months, resulting in the failure of timely availability of funds urgently needed for teaching [policy text analysis].

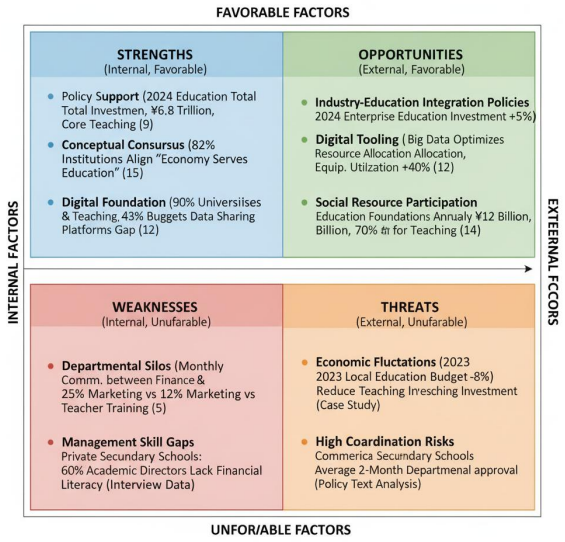

Fig.3.SWOT Matrix of Complementarity in Chinese Educational Institutions

5.Optimization Strategies: Practical Paths to Strengthen Complementarity

5.1.Establish a "Teaching-Oriented" Financial Philosophy

Establish a budget mechanism with priority to teaching needs: Require financial departments to conduct "teaching resource demand surveys" (covering 40% of teachers and 40% of students) before budget formulation, ensuring that the proportion of funds in core teaching areas (curriculum development, practical teaching) is not less than 60%.

Implement "thrifty school-running" and democratic supervision: Real-time publicize the use of teaching funds through a "financial disclosure platform", establish a supervision committee composed of faculty and staff representatives, and conduct voting deliberation on non-teaching expenditure projects exceeding 100,000 yuan.

Carry out interdisciplinary training: Incorporate "educational economics" into the compulsory courses for directors of teaching departments, and organize joint training between financial and teaching departments no less than 4 times a year to enhance coordination awareness.

5.2.Construct an Inter-Departmental Coordination Mechanism

Set up a resource allocation coordination committee: Led by the principal, the members include the director of the financial department, the director of the academic affairs department, and teacher representatives (accounting for 30%), holding monthly meetings to review teaching resource needs and budget execution.

Implement "teaching - finance" project-based management: For major teaching projects (such as program construction, training base upgrading), set up inter-departmental special teams to realize the whole-process coordination of "demand proposal - budget application - effect evaluation".

Establish performance-linked assessment: Incorporate "the satisfaction of teaching departments with financial services" (weight 40%) into the assessment of financial departments, and "resource use efficiency" (such as equipment utilization rate) into the assessment of teaching departments to force coordination.

5.3.Apply Digital Tools to Improve Management Accuracy

Build an integrated "teaching - finance" platform: Integrate data such as student scores, course offerings, and fund expenditures, and develop a correlation analysis module of "resource input - teaching output" to provide data support for budget adjustment.

Promote dynamic budget management tools: Adopt digital platforms such as FineReport to real-time monitor the progress of budget execution. When the over-expenditure/surplus of funds in a certain teaching area reaches 15%, automatically issue an early warning and suggest adjustment plans [12].

Establish a teaching demand prediction model: Based on historical data (such as the number of students selecting courses, demand for skill competitions), predict the teaching

resource needs for the next year through machine learning algorithms, and optimize the budget structure in advance.

5.4.Deepen the Integration of Production, Education, and Research and Social Cooperation

Promote "order-based" resource connection: Vocational colleges and enterprises co-build "teaching - production" bases. Enterprises provide equipment and teachers (economic resources), and schools carry out targeted talent training (teaching output), forming a closed loop of "resource input - talent transportation - enterprise feedback".

Expand social resource channels: Universities set up "education development funds" to attract enterprise donations (such as naming laboratories), and the donated funds are specifically used for teaching innovation; middle schools cooperate with communities to carry out "after-school services" to obtain community venue support (resource complementarity).

Standardize cooperation management: Establish an "industry-university-research cooperation evaluation system", requiring that the proportion of teaching-related investment in cooperation projects is not less than 70%, so as to avoid "emphasizing cooperation form over teaching effectiveness".

5.5.Improve the Supervision and Feedback Mechanism

Strengthen financial transparency and auditing: Issue a "Teaching Fund Use Report" every quarter, focusing on disclosing the expenditure details of core areas such as "teacher training" and "experimental teaching"; add a special item of "economic - teaching complementarity evaluation" in the annual audit.

Establish multiple feedback channels: Collect opinions on resource allocation through questionnaires (covering students, teachers, and enterprise partners), and departments with a feedback rate lower than 80% need to submit rectification plans.

Carry out complementarity effect evaluation: Set quantitative indicators (such as "input-output ratio of teaching funds", "resource waste rate"), conduct annual evaluations, and link the evaluation results with the budget for the next year.

Conclusion

The complementarity between economic and teaching activities in educational institutions is a three-level unity of "resource support - value feedback - goal coordination", rather than a simple linear relationship of "capital input - teaching output". Chinese educational institutions have advantages in realizing complementarity in terms of policy support and digital foundation, but problems such as departmental barriers and unbalanced resources restrict the synergy effect. Through the five strategies of "concept remodeling - mechanism construction - technology empowerment - cooperation expansion - supervision guarantee", the obstacles to realizing complementarity can be effectively solved, and the efficiency of educational management can be improved.

In the future, we can compare the complementarity models of educational institutions in different countries (such as transition economies like Belarus) to extract adaptive experiences of "low cost and high efficiency"; verify the impact coefficient of economic investment structure on teaching quality through panel data models to provide accurate basis for budget allocation; explore the application of artificial intelligence in "teaching demand prediction - dynamic budget adjustment", such as simulating the teaching effects of different resource allocation schemes based on digital twin technology.

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Research on the "Digital Divide" Problem in Artificial Intelligence Education Management Innovation

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KEYWORDS

Artificial intelligence ;
Education management ;
Educational innovation;
Digital divide;
Educational equity

ABSTRACT

The deep integration of artificial intelligence (AI) technology with education management is profoundly transforming education governance models towards precision, personalization, and intelligence. However, while the technological wave brings efficiency, it may also exacerbate or create new inequalities—the "digital divide . " Therefore, bridging the digital divide is a crucial measure to promote balanced educational development and achieve educational modernization. This paper expands research on the "digital divide" from the access level to the level of capabilities and benefits, and integrates it with theories of technological innovation and education, providing a new framework for promoting the healthy and sustainable development of AI-enabled education management.

INTRODUCTION

In the field of education management, the application of artificial intelligence is reshaping management processes and models in all aspects. Its potential to improve efficiency, liberate manpower and realize personalized services has attracted much attention . Governments and international organizations around the world have placed "AI + Education" at a strategic high position [1]. Practice shows that due to differences in economy, society, culture and existing education foundation, there are significant gaps in the opportunities and abilities of different regions, schools and groups of teachers and students to access, utilize and benefit from these AI management tools and platforms. This gap is the new form of "digital divide" in the field of education in the AI era. Therefore, bridging the digital divide is an important measure to promote balanced development of education and realize the modernization of education .

1.Definition and Application Research of Artificial Intelligence in Educational Management Innovation

1.1.Core Concepts

At the moment when global digital transformation and education modernization are converging, the foundation, goals and methods of artificial intelligence education are constantly changing . Intelligent education is based on big data and uses artificial intelligence technology to accurately calculate students' knowledge base, subject orientation, thinking type, emotional preference and ability potential. According to the laws of cognition and education, it scientifically implements teaching according to aptitude, realizes personalized training and comprehensive improvement of talent quality[2]. The characteristics of artificial intelligence education are applied to the fields of educational administration, school governance, teaching management, and student services, aiming to improve management efficiency, decision-making science and

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educational equity.

1.2.Innovative Application Scenarios of Artificial Intelligence in Educational Management

Educational management can be divided into three dimensions: "managing people" (students and teachers), "managing affairs" (teaching, research, and evaluation), and "managing things" (resources and facilities) . Artificial intelligence is permeating all these areas[3].

1. Student development and precision management .

Personalized learning path planning : AI analyzes students' learning behavior, grades, and knowledge gaps to customize dynamic learning plans and resource recommendations, achieving "one plan for each student".

Mental health and risk early warning . By analyzing students' behavioral data, facial expressions and voice (within compliance with regulations) on the campus network and digital platforms, as well as questionnaire results, AI can identify risks such as anxiety, depression, and bullying at an early stage, and provide timely warnings and interventions.

Learning planning and college application guidance . Based on massive amounts of data on universities, majors, and the job market, combined with student interest and ability profiles, AI can provide scientific career planning advice.

2. Teacher Support and Professional Development

Intelligent teaching assistant . AI helps teachers analyze student learning, automatically grade objective questions, and generate personalized practice questions, reducing administrative burdens and allowing teachers to focus more on instructional design and teacher-student interaction.

Precision teaching research and training . AI analyzes teachers' classroom recordings and videos (with authorization) to provide objective feedback on teaching language, interaction patterns, and pacing, supporting precision teaching research. Simultaneously, it delivers customized professional development resources to teachers.

3. Reform of Teaching Management and Quality Evaluation

Process-oriented evaluation system . Moving beyond a single outcome-based evaluation, AI can track the entire learning process of students and build a comprehensive evaluation model that includes multiple dimensions such as knowledge acquisition, ability improvement, participation, and collaboration skills.

Teaching quality monitoring and diagnosis . AI can perform macro-level analysis of teaching quality at the regional, school, and class levels, diagnose common problems, and provide data support for educational decision-making.

4. Intelligent administration and operation

Data and Decision Support . Provides schools and regional education administrators with visualized data dashboards to monitor the real-time operation of the education ecosystem and enable data-driven, scientific decision-making.

Intelligent scheduling and resource allocation . Taking into account multiple complex constraints such as teachers, classrooms, courses, and student course selection, AI can generate optimal scheduling schemes and resource allocation plans.

Campus safety and facilities management . Utilizing visual AI and IoT data, we can achieve campus safety monitoring and early warning, intelligent energy consumption control, and predictive equipment maintenance.

Fig.1. AI Innovation in Educational Management: Definition and Application Research

2.Research on the "Digital Divide" Problem in Artificial Intelligence Education Management Innovation

2.1.The New Connotation of the “Digital Divide”

The traditional "digital divide" primarily refers to the disparities in opportunities and capabilities among different social groups to access and use digital technologies (such as the internet and computers) in the digital age. These disparities can exacerbate social inequality and wealth disparity. It includes not only access to digital networks (the accessibility divide) but also proficiency in using digital tools and services (the usability divide). Now, in the context

of innovation in education management driven by artificial intelligence , the divide has evolved into an "intelligence divide," encompassing three levels:

First , the access chasm . Does the campus have the hardware, high-speed network, and basic digital environment to support the operation of AI systems?

Second , the usage gap . Do administrators, teachers, and students possess the digital education management skills and literacy necessary to effectively utilize AI management tools ?

Third , the value gap . Can we extract deep value from AI applications, including data-driven decision-making, personalized services, and business model innovation, rather than just superficial forms ?

2.2.A Three-Dimensional Analysis of the "Digital Divide" in AI-Driven Educational Management Innovation

1. Infrastructure and Data Access Gap

Manifestations: There are huge gaps between regions and campuses in terms of hardware (servers, sensing devices), high-speed and stable networks, and basic digital platforms required to support the AI management system[4] . More importantly, there is a data access gap—weak schools lack the ability to generate high-quality, structured data (such as the lack of a unified academic affairs and student registration system), which leads to their "data poverty" and makes it impossible to provide "fuel" for AI models.

Causes: Differences in economic development levels, fiscal investment, and historical debts. This is the most obvious, but not the only, gap.

2. The gap between data literacy and AI application capabilities

Manifestations: **Administrative Capability Gap :** Principals and administrators lack awareness and ability in "data-driven decision-making," failing to understand, interpret, or even question the AI system's suggestions, leading to "system stagnation" or "blindly following." **Teacher Capability Gap :** Teachers feel uncomfortable, distrustful, or lack the operational skills to integrate into AI management processes (such as using AI learning reports to guide teaching). **Teacher and Student "Being Managed" Competency Gap :** Teachers and students, as the subjects evaluated and guided by the AI system, lack understanding of its operational logic and their own data rights, leaving them in a passive and voiceless state[5].

Causes: Lack of training system, insufficient support for professional development, and slow organizational culture transformation. This is a deeper and more critical gap.

3. The gap between innovation benefits and empowerment outcomes

Performance: Even after connecting to the system and possessing basic usage capabilities, the " actual benefits " gained by different entities from AI management vary significantly. Schools with superior resources can leverage AI to "add icing on the cake," further strengthening their competitive advantage (such as more precise cultivation of top-notch innovative talents); while weaker schools may only be able to "barely maintain" basic management functions, unable to reach in-depth innovation. AI may solidify and amplify existing educational inequalities.

Causes: Differences in the innovation ecosystem (supporting resources, expert support, cultural atmosphere), potential biases in AI algorithms (training based on data from advantageous groups), and a singular definition of "benefit" in the evaluation mechanism (such as overemphasizing score improvement).

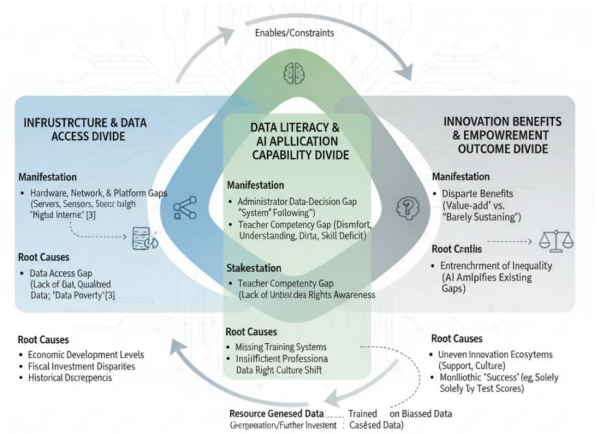

Fig.2. Three-Dimensional Analysis of the "Digital Divide" in AI Educational Management Innovation

3.Bridging the Gap: Innovation Pathways and Strategies

1. Policy guidance and balanced development:

Establish an AI+education management development index and baseline standards to clarify the level of intelligent management that schools should achieve at different stages of development.

Establish special transfer payments or public funds to prioritize providing lightweight, open-source, and customizable AI management tools and basic data platforms

to underdeveloped regions and schools.

Promote "group-style" development, encourage strong schools to support weaker schools, and share AI management experience, models, and even computing power.

2. Capacity building and competency enhancement:

"Educational data literacy" and "AI general knowledge" will be included in the mandatory training and assessment for principals and education administrators.

We conducted training for all teachers on "human-machine collaboration" management scenarios, focusing on how to interpret data and how to collaborate with AI to make better educational decisions.

Offer digital citizenship courses for students and parents to help them understand the principles, rights, and boundaries of AI management.

3. Technological Approach and Business Model Innovation:

Advocating for "lightweight and scenario-based" innovation: Instead of pursuing a "large and comprehensive" AI platform, we develop "micro-applications" that solve specific management pain points (such as intelligent class scheduling, dropout warning, and personalized homework distribution).

Promote open-source ecosystem and public models: Education authorities can take the lead in building open education data pools (after anonymization) and benchmark algorithm models to reduce technical barriers and costs.

Explore “human-centered AI design”: ensure that AI tools are transparent, explainable, and interventionable, and retain necessary human review and emotional communication links in management processes.

4. Ethical Norms and Institutional Development

Establish a school-level AI ethics committee, formulate norms for data collection, use, and auditing, and protect the privacy of teachers and students.

Improve the accountability mechanism for algorithms to ensure that AI-assisted decisions (such as evaluation and resource allocation) are traceable, appealable, and correctable.

We foster an organizational culture of "intelligent for good," emphasizing that AI empowers rather than replaces, with the ultimate goal of promoting holistic human development and educational equity.

Conclusion

Artificial intelligence (AI) presents a historic opportunity for the modernization of education management. AI-driven innovation in education management represents not only a tool upgrade but also a paradigm shift in the education governance system. Its goal is to leverage technology to build a more efficient, equitable, and flexible education management system, ultimately serving the holistic development of individuals. With the essence of education at its core, technology should become a supporting force for promoting high-quality education development. Therefore, promoting AI-driven innovation in education management must place bridging the digital divide and promoting educational equity at its core. Adhering to the fundamental value orientation of promoting educational equity and human development, while pursuing efficiency, greater attention should be paid to the deep integration of technological ethics and the principles of educational equity at the operational level, continuously exploring these principles, so that AI-driven innovation in education management truly becomes an equalizer for promoting high-quality education development .

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Study on Carbon Accounting and Emission Reduction Pathways of the Cement Industry in Liaoning Province

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KEYWORDS

Carbon accounting;
Cement;
Emission reduction pathways

ABSTRACT

The cement industry is a crucial basic raw material sector for national economic development, as well as a key area of energy consumption and carbon dioxide (CO_2) emissions. Taking the cement industry in Liaoning Province as the research object, this study systematically conducts research on carbon accounting and emission reduction pathways based on CO_2 emission data from fossil fuel combustion and production processes during 2000-2022. The accounting results indicate three key findings: the total industrial emissions present a three-stage characteristic of "fluctuating growth - peak - decline"; the emission structure has shifted from "combustion-dominated" to "balanced dual sources"; the emission reduction effect of combustion emissions is significant, while process emissions have become a bottleneck due to rigid constraints. Based on the accounting results, corresponding emission reduction policies are proposed. The research findings can provide data support and reference for the low-carbon transformation of the regional cement industry.

INTRODUCTION

Global climate change stands as one of the most pressing challenges confronting the world today. As the primary greenhouse gas, controlling carbon dioxide (CO_2) emissions is crucial for addressing this challenge [1]. Cement, as an indispensable core raw material for construction projects and infrastructure development, has played an irreplaceable role in the process of industrialization. However, carbon emissions from the cement industry remain persistently high, making it one of the most concerning sectors in terms of CO_2 emissions [2]. Emissions from cement, glass, and other industries account for approximately 50% of total industrial CO_2 emissions [3], making it a key carbon source in the industrial sector. The European Union's Carbon Border Adjustment Mechanism (CBAM) officially took effect in October 2023 and is currently in the transition period. It aims to ensure that imported goods pay the same carbon price as products within the EU, initially covering six categories of commodities: steel, cement, aluminum, electricity, hydrogen, and fertilizers. This initiative has reshaped global trade rules and is forcing the cement industry to accelerate its low-carbon transition [4].

The cement industry serves as a critical basic raw material sector for China's national economic development, while also being a key area of energy consumption and carbon dioxide (CO_2) emissions. China's cement output has remained above 2 billion tons for many consecutive years, with both its output and consumption accounting for over 50% of the global total [5], resulting in substantial energy consumption and CO_2 emissions[①].Therefore, achieving low-carbon development in the cement industry is vital for comprehensive emission reduction [6]. It is estimated that CO_2 emissions from China's cement industry account for approximately 80% of those in the building materials industry and over 10% of the national total CO_2 emissions, making it a key sector for China's carbon reduction efforts[②].Guided by the "dual carbon" goals (peaking carbon

[①]See National Carbon Market Information Network. https://www.cets.org.cn/zjsj/6512.jhtml.
[②]See Ministry of Ecology and Environment of the People's Republic of China.https://www.mee.gov.cn/zcwj/zcjd/.

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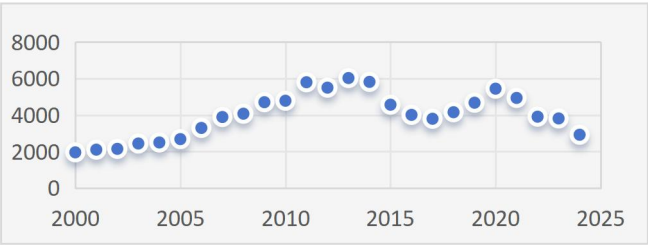
emissions before 2030 and achieving carbon neutrality before 2060), China has clearly articulated its targets. As an important basic industry of the national economy, the emission reduction progress of the cement industry directly affects the pace of achieving the country's "dual carbon" goals. Since 2021, with the decline in demand for cement products, China's cement output has shown a downward trend, and the contradiction of excess cement production capacity has become more prominent. In response, China has introduced a series of policy measures.

In January 2024, the Ministry of Ecology and Environment of the People's Republic of China issued the Opinions on Promoting the Implementation of Ultra-Low Emissions in the Cement Industry, proposing key tasks such as optimizing and adjusting the industrial structure, steadily advancing the ultra-low emission transformation of existing enterprises, coordinating the synergistic reduction of pollution and carbon emissions in the cement industry, and strengthening the whole-process refined environmental management.

In June 2024, the National Development and Reform Commission and other relevant departments issued the Special Action Plan for Energy Conservation and Carbon Reduction in the Cement Industry, setting the following targets by the end of 2025: controlling cement clinker production capacity at around 1.8 billion tons; ensuring that the proportion of production capacity meeting the benchmark energy efficiency level reaches 30%; completing the technological transformation or phasing out of production capacity below the baseline energy efficiency level; and reducing the comprehensive energy consumption per unit of cement clinker by 3.7% compared with 2020. During 2024—2025, the implementation of energy conservation and carbon reduction transformations and the renewal of energy-consuming equipment in the cement industry are expected to achieve energy savings of approximately 5 million tons of standard coal and reduce CO_2 emissions by around 13 million tons.



Source: Juhui Data Network（https://www.gotohui.com/）.

Fig.1. Cement Output of Liaoning Province (2000-2022)

As a core province of China's old industrial base in Northeast China, Liaoning Province, relying on its abundant limestone resources and improved industrial system, has become an important cement production base in North China. Its annual cement output is shown in Figure 1.

From the perspective of regional development needs, Liaoning Province is in a critical stage of transformation and upgrading as an old industrial base. As a traditional high-energy-consuming industry, the green transition of the cement industry is an important part of the optimization of the regional industrial structure. Currently, the cement industry in Liaoning Province is facing multiple challenges: on the one hand, backward production capacities such as traditional shaft kilns and wet-process kilns still remain, and the energy-saving transformation of advanced dry-process kiln production lines has not yet fully covered all enterprises; on the other hand, the substitution rate of new energy is less than 10%, coal remains the main energy source, and carbon emission intensity remains persistently high. Against this background, conducting targeted carbon accounting, tapping into emission reduction potential, and designing emission reduction pathways adapted to regional characteristics have become key initiatives to promote the green transition of Liaoning Province’s cement industry and support the achievement of regional "dual carbon" goals.

Building on this foundation, this study takes the cement industry in Liaoning Province as the research object and constructs a carbon accounting system. By comparing and analyzing advanced domestic and foreign emission reduction technologies and policy experiences, combined with Liaoning Province’s resource endowments and industrial foundation, emission reduction pathways are designed from dimensions such as technological upgrading, energy substitution, and policy guarantees. This research can provide data support for Liaoning Province to formulate precise emission reduction policies for the cement industry, as well as theoretical reference and practical experience for the green transition of high-energy-consuming industries in China’s old industrial bases in Northeast China.

As a prerequisite and foundation for precise emission reduction, carbon accounting is a core technical method to identify carbon emission sources and quantify emission reduction potential. Currently, China’s carbon accounting system for the cement industry has been formed with the Guidelines for Compiling Provincial Greenhouse Gas Inventories and the Guidelines for the Accounting Methods and Reporting of Greenhouse Gas Emissions from Cement

Production Enterprises as the core. However, regional-level accounting still suffers from insufficient refinement. Cement enterprises in Liaoning Province exhibit a distribution characteristic of "wide dispersion with partial concentration," and enterprises of different scales vary significantly in production processes, energy structures, and environmental protection facilities. Generic accounting methods struggle to accurately reflect the actual carbon emission situation of the regional industry, leading to a lack of precise data support for the formulation of targeted emission reduction policies.

1.Theoretical Basis

Cement production is a resource- and energy-intensive manufacturing process, accounting for approximately 12% to 15% of total industrial energy consumption, while cement production contributes 5% to 8% of global anthropogenic carbon dioxide (CO_2) emissions [7]. The emission sources included in the accounting and reporting of greenhouse gas emissions from cement production are: fossil fuel combustion emissions and process emissions [8]. In this study, CO_2 emissions from Liaoning's cement industry are calculated in accordance with the carbon accounting methods provided in the IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 2006) [9] and its revised version (IPCC, 2019) [10].

1.1.Fossil Fuel Combustion Emissions

Since the National Bureau of Statistics has not disclosed data on fossil fuel combustion emissions specifically for cement, this study estimates such data based on the fossil fuel consumption data of the non-metallic mineral products industry published by the Bureau. The non-metallic mineral products industry covers multiple sub-sectors including cement, glass, and ceramics, among which cement accounts for the largest proportion of carbon emissions. Therefore, this study uses the fossil fuel consumption data of the non-metallic mineral products industry as a proxy for cement-specific data in the accounting process.

(1) Calculation Formula.The CO_2 emissions from fuel combustion activities refer to the sum of CO_2 emissions generated by the combustion of various fuels during the accounting and reporting period of an enterprise, which is calculated in accordance with Formula (1).

$$E_{\text{combustion}} = \sum_{i=1}^{n} AD_i \times EF_i \qquad (1)$$

Where:

$E_{\text{combustion}}$ refers to the net CO_2 emissions generated from the combustion of fossil fuels consumed during the accounting and reporting period, with the unit of tonne of carbon dioxide (tCO_2).

AD_i refers to the activity level of the i-th type of fossil fuel during the accounting and reporting period, with the unit of gigajoule (GJ).

EF_i refers to the carbon dioxide (CO_2) emission factor of the i-th type of fossil fuel, with the unit of tonne of carbon dioxide per gigajoule (tCO_2/GJ).

i refers to the type of fossil fuel consumed on a net basis.

The activity level (AD_i) of the i-th type of fossil fuel during the accounting and reporting period is calculated in accordance with Formula (2).

$$AD_i = NCV_i \times FC_i \qquad (2)$$

Where:

NCV_i is the average net calorific value of the i-th type of fossil fuel during the accounting and reporting period, with the unit of gigajoule per tonne (GJ/t) for solid or liquid fuels, and gigajoule per 10,000 cubic meters (GJ/10,000 Nm^3) for gaseous fuels;

FC_i is the net consumption of the i-th type of fossil fuel during the accounting and reporting period, with the unit of tonne (t) for solid or liquid fuels, and 10,000 cubic meters (10,000 Nm^3) for gaseous fuels.

The carbon dioxide emission factor of fossil fuels is calculated in accordance with Formula (3).

$$EF_i = CC_i \times OF_i \times \frac{44}{12} \qquad (3)$$

Where:

CC_i is the carbon content per unit calorific value of the i-th type of fossil fuel, with the unit of tonne of carbon per gigajoule (tC/GJ);

OF_i is the carbon oxidation rate of the i-th type of fossil fuel, with the unit of percent (%).

1.2.Process Emissions

The carbon dioxide emissions resulting from the decomposition of carbonates corresponding to clinker exclude those generated by the decomposition of carbonates associated with the dust from the kiln stack (kiln inlet) and bypass exhaust dust, as well as the carbon dioxide emissions from the calcination of non-fuel carbon in the raw meal.

The carbon dioxide emissions during cement production are mainly derived from the carbon produced by the decomposition of carbonates and a small amount of organic carbon in the raw meal during high - temperature calcination, and such emissions can be considered approximately proportional to the cement output.

$$E_{\text{process}} = 0.525Ac \qquad (4)$$

Among them, 0.525 is the default process emission factor issued by the Cement Sustainability Initiative (CSI), with the unit of tonne of carbon dioxide per tonne of clinker (tCO_2/t clinker). This default factor assumes a calcium oxide (CaO) content of 65% in clinker and accounts for carbon dioxide emissions generated from the decomposition of magnesium carbonate. Ac refers to the output of cement clinker, with the unit of tonne (t).

2.Calculation Results

2.1.Results of fossil fuel combustion emission calculations

After calculation, the CO_2 emissions from fossil fuel combustion in Liaoning Province's cement products industry are shown in Table 1.

As it can be seen from Table 1:

(1) The overall emission trend shows a "three-stage" characteristic: fluctuating growth followed by a decline.

• Stage 1 (2000-2008): Slow fluctuation with modest growth. The total emissions fluctuated from 13.5153 million tonnes in 2000 to 25.6894 million tonnes in 2008, with an average annual growth rate of approximately 8.5%. A phased trough occurred in 2002 (12.1559 million tonnes), followed by rapid growth during 2004-2007, reflecting the capacity expansion and increased energy consumption of the cement products industry during this period.

• Stage 2 (2009-2013): Rapid surge to a historical peak. The total emissions increased from 24.7188 million tonnes in 2009 to 44.6815 million tonnes in 2013, with an average annual growth rate of about 15.8%—the highest rate across the entire period. The historical peak was reached in 2013 (44.6815 million tonnes), an increase of 80.8% compared to 2009. The main driving factors were the explosive growth in coke consumption and the steady rise in coal consumption.

• Stage 3 (2014-2022): Sustained decline and gradual stabilization. The total emissions decreased from the 2013 peak to 20.2238 million tonnes in 2022, with an average annual decline rate of approximately 8.2%. A precipitous drop occurred during 2015-2016, followed by slight fluctuating recovery in 2017-2020 and another slow decline after 2021. The overall trend of "decline followed by stabilization" reflects the restrictive effects of tightened environmental policies (e.g., the "dual carbon" goals and capacity regulation) on high-energy-consuming industries.

(2) The energy structure is centered on "coal + coke," with an extremely low proportion of clean energy.Coal and coke are the dominant energy sources, accounting for over 80% of total emissions. Coal has been the largest emission source throughout the period, with its share consistently ranging between 50% and 70% from 2000 to 2022. It reached a peak in 2013 (28.3852 million tonnes, accounting for 63.5%) and gradually decreased after 2016 (17.6939 million tonnes in 2022, accounting for 87.5%). Coke is the second-largest emission source with significant volatility: its share was 5%-8% during 2000-2008, surged rapidly in 2009-2013, and plummeted to below 5% after 2016, which is related to production process optimization and the use of alternative energy sources.

(3) Other energy sources account for a low proportion, with some categories phased out.Liquid fuels (crude oil, gasoline, kerosene, diesel oil, and fuel oil) collectively account for less than 10% of total emissions. Crude oil contributed moderately during 2000-2003 (1.3307 million tonnes in 2000) but was basically phased out after 2005. Fuel oil accounted for 2%-4% during 2001-2013 and dropped to below 2% after 2016.The proportion of clean energy such as natural gas is extremely low, nearly zero (≤0.0124 million tonnes) during 2000-2008. It grew slowly after 2009, reaching 0.2551 million tonnes in 2022, accounting for only 1.3%, reflecting the slow progress of clean energy substitution in the industry. Indirect emissions from electricity account for 3%-5%, peaking at 1.0571 million tonnes in 2021, with an overall slow upward trend, which is associated with the improvement in the industry's electrification level.

(4) The energy structure has shifted from "coal + coke" dual-driver to "coal-dominated"

single-driver.Before 2013, coal and coke together accounted for 80%-90% of total emissions, forming a dual-driver pattern. After 2016, the share of coke plummeted while the share of coal rose to over 85%, making the energy structure even more homogeneous. Insufficient clean energy substitution has become a bottleneck for emission reduction.

Year	Coal	Coke	Crude Oil	Gasoline
2000	1065.06	76.78	133.07	4.59
2001	1026.22	75.69	143.07	2.16
2002	981.22	128.92	1.09	3.33
2003	1086.06	48.10	3.53	2.11
2004	1635.23	71.77	0.15	3.54
2005	1721.08	100.44	0.00	4.45
2006	1729.27	157.36	0.63	5.32
2007	2167.90	195.88	2.48	11.67
2008	2167.90	195.88	2.48	11.67
2009	1853.61	369.52	1.78	11.96
2010	2276.56	658.32	0.00	24.80
2011	2173.57	661.38	0.18	36.27
2012	2811.11	1099.32	0.88	25.48
2013	2838.52	1229.93	1.12	25.62
2014	2430.05	1016.28	1.00	20.65
2015	2028.85	891.31	0.00	12.99
2016	1592.68	61.75	0.00	18.90
2017	1713.17	51.19	0.00	2.93
2018	1713.17	51.19	0.00	2.93
2019	2056.81	40.03	0.00	4.47
2020	2136.07	33.31	0.00	5.21
2021	2075.24	39.28	0.00	4.25
2022	1769.39	39.42	0.00	4.22

Table.1.CO_2 Emissions from Fossil Fuel Combustion in Liaoning Province’s Cement Products Industry (Unit: 10,000 tonnes)

Year	Kero-sene	Diesel Oil	Fuel Oil	Natural Gas	Electr-icity
2000	0.16	11.64	44.54	0.03	15.66
2001	0.13	9.78	79.07	0.03	16.23
2002	1.61	9.57	74.13	0.08	15.66
2003	0.22	16.10	85.29	0.10	18.85
2004	1.23	24.49	89.19	0.41	36.76
2005	1.04	33.13	95.43	0.41	39.21
2006	1.92	29.60	103.26	0.96	43.12
2007	1.39	41.98	87.60	1.24	58.80
2008	1.39	41.98	87.60	1.24	58.80
2009	1.01	53.93	113.41	3.96	62.69
2010	0.85	63.81	73.21	11.36	74.61
2011	0.19	85.94	81.67	32.86	91.91
2012	0.00	130.68	80.18	60.68	90.93
2013	0.06	175.60	79.93	25.51	91.86
2014	0.03	22.97	81.51	34.18	94.29
2015	0.66	51.39	48.73	26.16	52.90
2016	0.03	45.20	50.32	12.32	60.19
2017	0.00	39.04	44.20	10.32	68.03
2018	0.00	39.04	44.20	10.32	68.03
2019	0.00	39.54	67.63	18.57	74.17
2020	0.00	43.45	54.19	21.13	97.78
2021	0.01	43.49	49.34	28.41	105.71
2022	0.12	49.14	37.38	25.51	97.19

Table.2. Continued

2.2.Process emission results

After calculation, the process CO_2 emissions of Liaoning Province’s cement products industry are shown in Table 3.

Year	Process Emissions	Year	Process Emissions
2000	1026.31	2012	2889.48
2001	1103.26	2013	3165.73
2002	1126.52	2014	3055.80
2003	1280.86	2015	2398.05
2004	1310.26	2016	2105.76
2005	1407.35	2017	1993.41
2006	1729.25	2018	2181.85
2007	2043.93	2019	2455.64
2008	2139.06	2020	2859.68
2009	2470.04	2021	2592.93
2010	2512.56	2022	2053.25
2011	3044.87		

Table.3. Process CO_2 Emissions of Liaoning Province’s Cement Products Industry (Unit: 10,000 tonnes)

As it can be seen from Table 2, the process emissions increased from 10.2631 million tonnes in 2000 to 20.5325 million tonnes in 2022, with a cumulative growth of 99.97% (nearly doubling). This reflects the "rigid growth" attribute of process emissions, which is directly driven by capacity expansion. There was no consecutive negative growth for more than 3 years throughout the period; even during the period of tightened emission reduction policies (after 2013), the characteristic of "rebound after decline" persisted. This highlights the strong correlation between process emissions and production scale — substantial emission reduction can only be achieved when there is a significant contraction in output or revolutionary optimization of production processes.

The underlying reasons are as follows: Firstly, the strength of cement is highly dependent on clinker (a product of calcium carbonate decomposition), and there are technical bottlenecks in raw material substitution (the current upper limit of waste residue substitution ratio is approximately 50%), making it impossible to completely decouple from calcium carbonate. Secondly, the potential for process-based emission reduction is limited: the new dry-process technology has become the mainstream (accounting for over 90%), and the emission reduction potential of traditional processes has been basically exhausted, while next-generation low-carbon technologies (such as electrochemical calcination and

carbon capture) are still in the R&D stage. Thirdly, the production capacity base is large. Even if output declines, idle capacity may lead to a cycle of "overcapacity → illegal production → emission rebound."

3.Carbon Emission Reduction Pathways for the Cement Industry in Liaoning Province

3.1.Accelerate Clean Energy Substitution and Promote Energy-Saving Technology Upgrades

(1) Increase the Proportion of Clean Energy Utilization.In the current fossil fuel combustion emissions of Liaoning's cement products industry, coal accounts for as high as 87.5%, while clean energy such as natural gas accounts for only 1.3%. Although combustion emissions have dropped significantly between 2013 and 2022, there remains enormous potential for clean energy substitution. In the short term (2023-2025), priority should be given to promoting natural gas as a substitute for coal in core production processes such as rotary kilns and drying systems, aiming to increase the share of natural gas in total energy consumption to 5%-8%. In the medium to long term (2026-2030), leveraging Liaoning's local advantages in renewable energy development such as wind and solar power, pilot projects for electricity-driven calcination technologies (e.g., electric kilns) should be launched to gradually reduce reliance on fossil energy and fundamentally optimize the energy structure.

(2) Promote Upgrades of Energy-Saving Technologies.The rapid growth of combustion emissions from 2000 to 2013 was closely linked to low energy efficiency. Despite improvements after 2016, the energy consumption per unit product remains higher than the national advanced level. It is necessary to vigorously promote high-efficiency combustion systems (e.g., low-nitrogen burners) to improve fuel combustion efficiency, and popularize waste heat recovery and utilization technologies such as waste heat power generation at kiln tails to fully tap energy potential. Through this series of energy-saving technology upgrades, combustion emissions will be further reduced.

3.2.Strengthen New Raw Material Substitution and Enhance Technological Empowerment

(1) Large-Scale Application of Raw Material Substitution.Process emissions have risen from 43.16% in 2000 to 50.38% in 2022, becoming a bottleneck in emission reduction. The core reason is that limestone remains the dominant raw material, with insufficient substitution by industrial waste residues. The admixture ratio of industrial waste residues such as fly ash, slag, and steel slag should be increased. Meanwhile, pilot projects for new low-carbon raw materials that do not rely on cement clinker should be promoted in segmented fields such as precast components, with gradual expansion of application scope upon technological maturity.

(2) Break Through Bottlenecks in Process Innovation.Currently, the proportion of new dry-process cement production technology in Liaoning's cement products industry has exceeded 90%. The emission reduction potential of traditional processes has been basically exhausted, while process emission intensity remains at a high level. Existing processes need to be optimized and upgraded, including the upgrading of precalciner systems and the adoption of low-temperature calcination technologies to reduce the temperature required for calcium carbonate decomposition and minimize process emission losses. In addition, increase investment in cutting-edge technologies such as carbon capture, utilization, and storage (CCS), and select large-scale cement enterprises for pilot projects. It is expected that large-scale application of CCS technology will be achieved by 2030, enabling a reduction rate of over 30% per plant.

Construct a "low-cost, high-emission-reduction" technology combination system, and promote the implementation of various technologies in priority order:

High priority: Popularize mature technologies such as natural gas substitution for coal, waste heat recovery and utilization, and industrial waste residue substitution for clinker.

Medium priority: Promote advanced technologies such as new dry-process optimization and low-nitrogen burners, as well as pilot projects for alkali-activated cementitious materials (the former optimizes combustion emissions, while the latter achieves significant process emission reduction in pilot fields).

Medium-low priority: Layout cutting-edge technologies such as electric kiln calcination, renewable energy coupling, and large-scale CCS application to lay the foundation for long-term deep emission reduction.

3.3.Combine Rigid Constraints with Flexible Measures to Improve Policy Mechanisms

(1) Strengthen Rigid Constraints.Improve the emission accounting system by incorporating the dual indicators of "combustion emission intensity + process emission intensity" into environmental assessments, preventing enterprises from achieving emission reduction targets merely by reducing production while neglecting emission intensity optimization. Strictly implement production capacity control policies, prohibit new cement production capacity, and promote a linked mechanism of "production capacity replacement + off-peak production" to ensure stable emission reduction effects.

(2) Improve Incentive Mechanisms.Establish fiscal subsidy policies: Provide enterprises with a subsidy of 50-100 yuan per ton of CO_2 reduced for emission reduction projects such as natural gas substitution, high admixture ratio of waste residues, and CCS technology application to lower their emission reduction costs. Offer financial support by setting up special loans for low-carbon technologies to reduce the financing threshold and costs of technological transformation. Encourage cross-industry cooperation between cement enterprises and steel enterprises to realize the synergistic utilization of raw materials such as steel slag and form a joint force for emission reduction.

3.4.Guide Synergistic and Healthy Development of Demand

(1) Optimize the Terminal Demand Structure.Promote low-carbon cement products such as high-performance concrete, precast components, and fiber-reinforced cement products. These products have superior performance and can reduce cement consumption per unit project. Mandate the use of a certain proportion of low-carbon cement products in infrastructure projects such as transportation and municipal engineering, integrate cement emission reduction with green buildings and new urbanization construction, and guide terminal demand toward low-carbon transformation.

(2) Curb Ineffective Demand.Resolutely phase out outdated production lines , as these lines are inefficient and high-emission. Their elimination will avoid the "inefficient production - high emission" cycle caused by overcapacity. Guide industry integration, increase industry concentration through mergers and acquisitions, reduce emission costs per unit product via large-scale production, and enhance the overall emission reduction capacity of the industry.

Conclusion

Based on the IPCC Guidelines for National Greenhouse Gas Inventories and China's carbon accounting standards for the cement industry, this study calculates carbon emissions using statistical data of Liaoning Province's cement industry from 2000 to 2022 and explores potential emission reduction pathways. The core conclusions are as follows: The total carbon emissions of Liaoning's cement industry have shown a "fluctuating downward" trend, with emissions decreasing in recent years; however, structural contradictions persist. Accounting results indicate that process emissions and fossil fuel combustion emissions are the primary sources of carbon emissions. Based on these findings, this study puts forward targeted measures, including accelerating the replacement of clean energy, promoting the upgrading of energy-saving technologies, advancing the substitution of new raw materials, strengthening technological empowerment, enforcing rigid constraints, improving incentive mechanisms, and guiding the coordinated and healthy development of market demand.

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Random Processes In The Parametric Control Of A Mobile Robot Based On Pattern Recognition Algorithms

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KEYWORDS

Mobile robot;
Parametric control;
Random process;
Pattern recognition;
Probability distribution;
Mathematical model;
Visual navigation

ABSTRACT

Mobile robots operating in unstructured real-world environments face inherent uncertainties from dynamic obstacles, variable terrains, and unpredictable events, which pose significant challenges to their control systems. This study focuses on the integration of random process theory and pattern recognition algorithms to optimize the parametric control of mobile robots. First, it systematically analyzes the probabilistic characteristics of discrete and continuous random variables, and explores typical discrete distribution laws (Bernoulli distribution, Binomial distribution, Poisson distribution) that underpin the modeling of stochastic phenomena in robotic systems. Second, it constructs a mathematical model for parametric control integrating pattern recognition, encompassing core components such as sensor data processing, state estimation (e.g., Kalman filtering), pattern recognition algorithms, and parameter control strategies. Finally, a case study of an indoor visual navigation system is presented, where an improved path-based algorithm achieves real-time image processing (≤40ms per frame) to meet the requirements of autonomous navigation. The research verifies that the synergy between random process theory and pattern recognition can enhance the adaptability and intelligence of mobile robots in uncertain environments, providing a theoretical and practical basis for the development of autonomous robotic systems.

INTRODUCTION

The field of robotics has experienced a profound revolution, marked by the increasing integration of sophisticated pattern recognition algorithms into the control and decision-making processes of mobile robots. In this era of automation, autonomous robots are venturing into dynamic and intricate environments, encompassing terrains both known and uncharted, industrial facilities, hospitals, and even urban settings. The efficacy of these mobile robots lies not only in their physical capabilities but equally in their capacity to perceive, understand, and adapt to the world around them.

The paramount challenge of robot control in real-world scenarios is an inherent uncertainty. In these unstructured environments, where dynamic obstacles, varying terrain, and unpredictable events are the norm, a robust control system is essential. Pattern recognition algorithms, often rooted in machine learning and computer vision, are at the forefront of addressing these challenges. They enable robots to sense, interpret, and respond to their surroundings with a level of intelligence that was once confined to the realm of science fiction.

1.Probabilistic Characteristics Of Discrete And Continuous Random Variables

1.1.Random Variables

The field of robotics, particularly concerning the control of mobile robots, has undergone a significant transformation due to the widespread integration of pattern recognition algorithms. These algorithms serve as a foundational element in numerous robotic functionalities, encompassing navigation, perception, decision- making, and interactions within complex physical

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and social environments. However, the performance and adaptability of these algorithms are intricately tied to the stochastic and unpredictable nature of the real-world scenarios. To effectively tackle these challenges, a profound comprehension of the probabilistic traits of random variables, which form the core elements of these robotic systems, is essential[1,2].

$$\mu_X = x_1 p_1 + x_2 p_2 + \cdots + x_k p_k = \sum x_i p_i$$

The mean of a discrete random variable is its weighted average, calculated by multiplying each value by its probability and summing the products, known as the expected value of X.

To illustrate random variables, consider the random experiment of rolling a dice where the possible outcomes range from 1 to 6. If X represents the outcome of this experiment, the sample space comprises outcomes {1, 2, 3, ..., 6}.

Mathematically, X = 1, 2, 3...6, corresponding to the outcomes of the dice roll. [3] In simplifying and generalizing this concept mathematically, a single dice roll is represented as a box in a figure. Extending this to n trials shows separate boxes, signifying outcomes from n such random events.

1.2.Discrete Random Variables

A cornerstone of probabilistic modeling in the realm of mobile robotics is the concept of a random variable.A discrete random variable X has a countable number ofpossible values. [4] Example: Let X represent the sum of two dice.

Then the probability distribution of X is as follows:

X	2	3	4	5	6	7	8	9	10	11	12
P(X)	1/36	2/36	3/36	4/36	5/36	6/36	7/36	8/36	9/36	10/36	11/36

Table .1. Probability distribution of X

To graph the probability distribution of a discrete random variable, construct a probability histogram:

$$\sigma_x^2 = (x_1 - \mu_X)^2 p_1 + (x_2 - \mu_X)^2 p_2 + \cdots + (x_k - \mu_X)^2 p_k = \sum (x_i - \mu_X)^2 p_i$$

2.Typical Laws of Distribution for Discrete Random Variables

Within the framework of this coursework, we delve into an array of distribution laws for discrete random variables, including but not limited to:

1. Bernoulli Distribution: Employed to model binary outcomes, such as the success or failure of a single trial[5].
2. Binomial Distribution: Utilized to describe the probability of a specific number of successful outcomes within a fixed number of independent trials[6].
3. Poisson Distribution: Integral in representing the probability of a certain number of events occurring within a specified time interval[7].

2.1.The Bernoulli distribution

The Bernoulli distribution is one of the easiest distributions to understand because of its simplicity. It is often used as a starting point to derive more complex distributions.

A Bernoulli distribution is a discrete distribution with only two possible values for the random variable. The distribution has only two possible outcomes and a single trial which is called a Bernoulli trial. The two possible outcomes in Bernoulli distribution are labeled by n=0 and n=1 in which n=1 (success) occurs with probability p and n=0 (failure) occurs with probability 1-p, and since it is a probability value so 0<=p<=1.

The probability mass function (PMF) of a Bernoulli distribution is defined as Figure1.If an experiment has only two possible outcomes “success” and “failure,” and if p is the probability of success, then ⋯

Another common way to write this is:

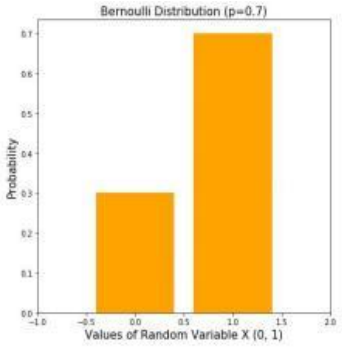

Fig.1. Graph ofBernoulli distribution

Properties of a Bernoulli distribution: [8]

(1) There are only two possible outcomes a 1 or 0, i.e., success or failure in each trial.

(2) The probability values of mutually exclusive events that encompass all the possible outcomes need to sum up to one.

(3) If the probability of success is p then the probability of failure is given as 1-p.

The probability values must remain the same across each successive trial. Each event must be completely separate and have nothing to do with the previous event. i.e., the probabilities are not affected by the outcomes of other trials which means the trials are independent.The expected value for a random variable, X, from a Bernoulli distribution can be given as:

E[X] = 1*(p) +0*(1-p) = p, for example ifp=0.6, then E[X] =0.6 The mean of Bernoulli random variable(X) is

E[X] = 1(p) +0(1-p) = p

The variance of Bernoulli random variable is V[X] = E[X ^{2}]-[E(X)]^2 = 1^2 p+0^2 (1-p)-p^2 =p(1-p)

2.2.The Binomial distribution

Poisson distribution is the discrete probability distribution which represents the probability of occurrence of an event r number of times in a given interval of time or space if these events occur with a known constant mean rate and are independent of each other. This type of probability is used in many cases where events occur randomly, but with a known average rate. The number of events that happen during an interval is dependent on the time elapsed rather than the total time available. The Poisson distribution can be applied to time-sensitive processes such as text messages sent per minute and phone calls received per second. Poisson distribution can help us determine how often we may expect an “event” such as finding customers in line or the number of accidents that occur per hour.[13]

The following are the key criteria that the random variable follows the Poisson distribution:[14]

1) Individual events occur at random and independently in a given interval. This can be an interval of time or space.

2) The mean number of occurrences of events in an interval (time or space) is finite and known.

3) The mean number of occurrences is represented using $[latex]\lambda[/latex]$

The random variable X represents the number of times that the event occurs in the given interval of time or space. If a random variable X follows Poisson distribution, it is represented as the following:[15] X ~ Po ($[latex]\lambda[/latex]$)

In the above expression, [latex]\lambda[/latex] represents the mean number of occurrences in a given interval. Mathematically, the Poisson probability distribution can be represented using the following probability mass function:

$$[latex] \setminus LargeP(X = r) = \frac{e^{-\lambda} * \lambda^r}{r!} [/latex]$$

In the above formula, the [latex]\lambda[/latex] represents the mean number of occurrences, r represents different values of random variable X.

3.Mathematical model of the parametric control of a mobile robot based on pattern recognition algorithms

3.1.Parametric Control and Pattern Recognition Integration

The integration of parameter control and pattern recognition represents a key advance in the field of robotics, providing robots with enhanced adaptability and intelligence in complex and uncertain environments. Parametric control forms a fundamental aspect of robot control systems, allowing fine-tuning and adjustment of various parameters that control robot behavior. Pattern recognition enables robots to interpret complex data to make intelligent decisions based on observed patterns. Algorithms designed for pattern recognition analyze sensor data, images or environmental inputs to identify recurring patterns or anomalies. By utilizing parametric control to adjust behavior and pattern recognition to interpret environmental cues, robots gain the ability to dynamically respond to real-world scenarios based on context.

3.2.Considerations for mathematical models and what must be included

In order to build a parameter control mathematical model based on pattern recognition algorithms, we need to consider several basic components: (1) Sensor data processing: One of the initial steps is to process sensor data, which usually includes data from cameras, lidar, ultrasonic sensors, etc. information.

(2) State estimation: Accurate state estimation is crucial for effective control. Mobile robots must know their position, orientation, and speed relative to the environment. This is achieved through sensor fusion techniques such as Kalman filtering, which combines data from multiple sensors to produce a reliable estimate of the robot's state. (3) Pattern recognition algorithm： Pattern recognition algorithms play a central role in understanding and interpreting the environment. These algorithms are trained to detect objects, identify obstacles, and recognize landmarks, allowing the robot to make informed decisions based on the patterns it recognizes. (4) Parameter control strategy: Parameter control strategy contains high-level decision-making process, which depends on parameters extracted from sensor data and pattern recognition. The policy specifies how the robot should navigate, make decisions, and achieve mission goals. Key components may include path planning, trajectory generation, and obstacle avoidance.

3.3.Display and discussion of cases and actual use of data models

To illustrate the application of mathematical models, we design a visual navigation system for autonomous navigation in indoor environments. [28, 29] The system consists of three main modules: image preprocessing, path recognition and path tracking. Its workflow is shown in Figure 9. The original input image of the robot vision system is a continuous digital image obtained after A/D (analog/digital) conversion by the image acquisition card. When the system works, first, the image preprocessing module selects various target points useful to the robot (including guide lines in the path, turn signs, destination signs, etc.) with appropriate resolution and segmentation thresholds on the original
input image. It will eliminate the noise points, and the set of these points constitutes the target's support point set (support). The path recognition module detects guide lines and various signs in the scene based on the target support point set, and the guide lines and signs can be combined to obtain the required path information. Finally, based on the path information provided by the path identification module, the path tracking module calls different computing modules to
provide input parameters for the motion control system of the mobile platform in two situations: straight driving and turning.

In order to realize and make full use of image sequence information and abandon overly complex processing algorithms, an improved algorithm based on paths is proposed. Under the premise of accurately understanding the road image, the improved algorithm can process each frame of image within 40ms, which can meet the real-time requirements of the system (25 frames/s).

Conclusion

In summary, the synergy between stochastic processes and pattern recognition in mobile robot control not only provides a solid theoretical framework for solving uncertainty problems, but also infuses machines with "intelligence" in environmental perception and autonomous decision-making through its fusion model. Looking to the future, developments in this field will inevitably give rise to more adaptive, learning-capable, and intelligent robotic systems, whose applications will extend to every corner of industry, from manufacturing to social services, profoundly changing human production and lifestyles. However, technological leaps also bring ethical and social responsibility challenges. Guiding this transformation towards a direction that benefits humanity will be a crucial issue we must collectively address in the next stage.

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Analysis of Spatial Leverage In Industrial Tourism

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KEYWORDS

Mobile robot;
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ABSTRACT

This article analyzes the spatial leverage of industrial tourism, assesses its development potential, and proposes a model for interaction between industry participants. The methodological framework utilizes methods of analysis and synthesis, generalization and classification, and modeling. The information base includes regulatory documents of the Republic of Belarus (RB), scientific articles, periodicals in the field of industrial tourism, industrial tourism development methodologies, and statistical digests on the topic under study. The study allowed us to assess the spatial organization of industrial tourism, the interactions between industrial tourism participants, and develop a comprehensive approach to its development, creating a system for exchanging experience across various industries. This study also identified the expected outcomes of industrial tourism development for its participants in the republic.

ВВЕДЕНИЕ

Устойчивое пространственное развитие подразумевает комплексное сбалансированное развитие региона, которое формируется под влиянием экономических, социальных, экологических, институциональных факторов. В связи с ростом материального положения у населения появляется возможность использовать по своему усмотрению свободное время. Наиболее доступным по региональным особенностям можно назвать промышленный туризм, который привлекает экскурсантов к кратковременным маршрутам. Поэтому , можно отметить особое место промышленного туризма в перечне предлагаемых туристическими фирмами актуальных продуктов [1, 2, 3].

1.Основная Часть

Несмотря на актуальность инновационных идей в туристической сфере в ней отсутствует систематизированная информация о туристических объектах.

В связи с вышесказанным, можно говорить о том, что формирование и развитие рынка промышленного туризма в России является весьма актуальной темой для проведения комплексного научного исследования, ориентированного на решение приоритетных задач социально-экономического развития и обеспечения устойчивой динамики роста российских туристских дестинаций (центров-территорий с необходимыми удобствами, сервисами обслуживания и услугами для обеспечения всевозможных нужд туристов при посещении промышленных предприятий) .

Многоотраслевая экономика Республики Беларусь способствует разностороннему развитию направлений промышленного туризма.

Число промышленных организаций в 2024 году составляет 17 377 ед, горнодобывающей промышленности – 38, обрабатывающей промышленности – 16695, снабжения электроэнергией, газом, паром, горячей водой и кондиционированным воздухом - 250 ед, число организаций строительства (на конец года) 8 839 ед. Кроме того, в республике насчитывается 66 564 ед. торговых объектов, а общественного питания – 16 255 ед. [4].

Такой широкий диапазон возможностей позволяет

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клиентам иметь широкий выбор рассматриваемого объекта внимания.

В настоящее время услуги промышленного туризма в Республике Беларусь оказывают более 50 предприятий, и их количество постоянно растет, а этому способствует изменение их приоритетов, которым требуется максимум впечатлений, комфорта от тура, поэтому совмещают традиционный осмотр с посещением индустриальных объектов. В результате экскурсий посетители получают новые знания, а у предприятия появляется возможность знакомства посетителей с производством, технологиями, продукцией, методах работы и внутренней жизни [5].

Среди наиболее востребованных для промышленного туризма предприятий оказались: «Белорусский автомобильный завод (БЕЛАЗ)» (21,8 %), кондитерская фабрика «Коммунарка» (12,3 %), «Минский тракторный завод (МТЗ)» (8,9 %), «Минский автомобильный завод (МАЗ)» (8,3 %) и кондитерская фабрика «Спартак» (3,2 %). Также респондентами были отмечены мясо-молочные комбинаты, стеклозавод «Неман», шахты предприятия «Беларуськалий», «АТЛАНТ», «БЕЛДЖИ», хлебозаводы и предприятия по производству кондитерских изделий, «Белорусский металлургический завод (БМЗ)», «Красный пищевик», «Гомсельмаш», пивоваренная компания «Аливария», «Лидское пиво», «Белшина» и другие [6].

Для Беларуси, как индустриально развитого государства сфера промышленного туризма обладает особой значимостью, поскольку открывает возможности демонстрации национальных достижений. Согласно проведенным Белорусским институтом стратегических исследований (БИСИ) социологическим исследованиям (в рамках проекта "Пульс общества"), отечественная промышленность в сознании граждан ассоциируется с брендом государства.

Российский опыт развития промышленного туризма во многом является прорывным. На уровне Союзного государства организация промышленного туризма помогает демонстрировать успешную и эффективную интеграцию, прогресс сторон в импортозамещении и техническом суверенитете.

Поэтому особенное внимание заслуживает вопрос пространственной организации промышленного туризма. С использованием инструментария ГИС, геостатистических и пространственных методов анализа выявляются закономерности территориальной структуры демонстрационных объектов и профильных предприятий.

1.Установлено, что гетерогенность их размещения детерминирована триадой ключевых факторов: близость к городским агломерациям как основным рынкам-источникам, уровень индустриального развития региона и степень транспортной доступности, которая определяет потенциал пространственных связей между объектами [7;8].

2. Активно разрабатываются концептуальные модели развития. На смену ранним подходам, заимствованным из зарубежного опыта (музейный тип, модель «базовой точки»), пришли новые парадигмы, обусловленные усилением межотраслевой интеграции [9; 10]. Современные модели, такие как креативные индустриальные парки, рекреационно-развлекательные комплексы и низкоуглеродные сообщества, отражают эту тенденцию. Китайские исследователи подчеркивают, что выбор оптимальной модели управления и развития должен быть строго контекстуальным и базироваться на уникальном сочетании промышленного уровня, функционального зонирования и культурной специфики города [11;12].

3. Огромное количество исследований посвящено выработке стратегических подходов к управлению с позиций как государства, так и предприятий. Учитывая доминирующую роль государственных компаний в промышленном секторе Китая, акцентируется необходимость адаптации планирования к местным условиям и политических инноваций в рамках социалистической рыночной экономики. Основными стратегическими императивами признаются создание эффективных институциональных и нормативных систем, а также формирование сильных отраслевых брендов и расширение цепочек создания стоимости через синергию с другими индустриями [13; 14].

Несмотря на достигнутые результаты, научное поле имеет ряд нерешенных задач. Анализ пространственной структуры все еще остается недостаточно систематизированным. Наблюдается явный географический крен в сторону изучения прибрежных и старопромышленных регионов, в то время как новые комплексные исследования на общенациональном уровне практически отсутствуют.

Приведенный анализ показывает, что научный фокус

китайских исследователей направлен на решение конкретных прикладных задач в области пространственной организации, моделирования и стратегического управления промышленным туризмом. Однако сами эти исследовательские направления базируются на определенном понимании сущности и границ изучаемого феномена. Это, в свою очередь, актуализирует необходимость обращения к фундаментальной основе — самому определению понятия

Систематизация подходов к определению промышленного туризма выявляет ключевые различия в фокусе различных научных школ. Российская школа акцентирует внимание на организационно-практическом аспекте, западная — на социокультурном и эмпирическом опыте туриста, а китайская — на экономической целесообразности и интеграции в производственные цепочки.

Однако при всей глубине анализа ни одна из существующих дефиниций не охватывает феномен промышленного туризма комплексно, как системный объект управления, который одновременно решает задачи трех ключевых субъектов: туриста, предприятия и территории. Для восполнения этого пробела и формирования целостного видения, соответствующего целям исследования, предлагается следующее расширенное авторское определение:

Промышленный туризм — это управляемый социально-экономический процесс трансформации замкнутых производственных пространств (действующих, исторических или проектируемых) в открытые полифункциональные площадки посредством их интеграции в сферу туристских услуг с целью:

Для туриста — удовлетворения специфических когнитивных, профориентационных и ностальгических потребностей через эмпирическое погружение в индустриальную культуру и производственные процессы.

Для предприятия — использования его как стратегического инструмента нематериального маркетинга, который позволяет «очеловечить» бренд, продемонстрировать инновационность, прозрачность и качество, а также повысить лояльность как потребителей, так и сотрудников.

Для территории — применения его в качестве драйвера диверсификации экономики, инструмента ребрендинга депрессивных или монопрофильных регионов и катализатора устойчивого развития, основанного на уникальном промышленном потенциале.

Таким образом, промышленный туризм рассматривается не просто как нишевый вид досуга, а как комплексный объект управления на трех уровнях (микро-, мезо- и макро-), существующий на стыке производства, образования, культуры и территориального маркетинга.

В научной литературе накоплен значительный опыт анализа влияния туризма на социально-экономическое развитие, и часто подчеркивается его способность противостоять внешним шокам. Однако промышленный туризм вносит в эту картину свою специфику.

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Для территории — применения его в качестве драйвера диверсификации экономики, инструмента ребрендинга депрессивных или монопрофильных регионов и катализатора устойчивого развития, основанного на уникальном промышленном потенциале.

Потенциал развития промышленного туризма заключается в его способности выступать гибридной стратегией для ревитализации депрессивных и старопромышленных регионов, интегрируя в себе как механизмы «умного сжатия», так и стимулы для нового роста. Леверидж уникального промышленного наследия и естественной «цепочки опыта», заложенной в производственной логике, позволяет создавать уникальные и конкурентоспособные туристические продукты.

Промышленный туризм связан с организацией экскурсий и регулярных туров на передовые действующие или когда-то действовавшие промышленные предприятия страны. В числе основных потребителей объектов промышленного туризма могут выступать не только простые туристы, но и школьники, студенты, предприниматели и руководители предприятий, журналисты, каждый из которых будет преследовать свою цель при посещении производства.

Достоинства организации промышленного туризма очевидны для всех сегментов. Для туристов это прекрасная возможность увидеть, как производят их любимые продукты, а предприятию это позволяет укрепить репутацию компании и увеличить продажи. Для местных органов власти – это инвестиции в территориальное развитие, для населения– стимул развития бизнеса в регионе.

В белорусском информационном пространстве закрепилось представление о промышленном туризме как динамично развивающейся области и одном из важных направлений развития туристической индустрии, объединяющем образовательные, деловые и культурные аспекты. Делается акцент на привлечении туристов к посещению предприятий через организацию экскурсий и других событий (семинары, мастер-классы, выставки): «Промышленный туризм в стране развивается интенсивно. Сегодня более 130 предприятий и организаций развивают это направление. Они имеют определенную базу, наработки и мотивацию развивать промышленный туризм») рисунок 1 .

Сегодня промышленный туризм превращается в один из действенных инструментов по выводу предприятий на новые рынки, получению идей для его стратегического развития, экскурсионной индустриализации.

Как показывает сложившаяся динамика посещения предприятий, использование цифровых технологий позволяет туристу до начала путешествия ознакомиться с предприятием и выбрать для посещения наиболее интересное.

Поэтому сейчас такие туристические мероприятия являются туристической рекламой, способствующую их превращению в индустрию. В качестве этого увеличивается воздействие средств видеокоммуникаций на рекламу познания и развлечения, которые, в конечном счете, оказываются встроенными в комплекс туристического обслуживания [15].

В настоящее время цифровые решения, информационно-коммуникационные технологии стали глобальными трендами в сфере туризма и гостеприимства, многие государства наращивают их внедрение в воспроизводственные процессы с целью повышения социальной, экономической, экологической эффективности использования туристско-рекреационного потенциала [16].

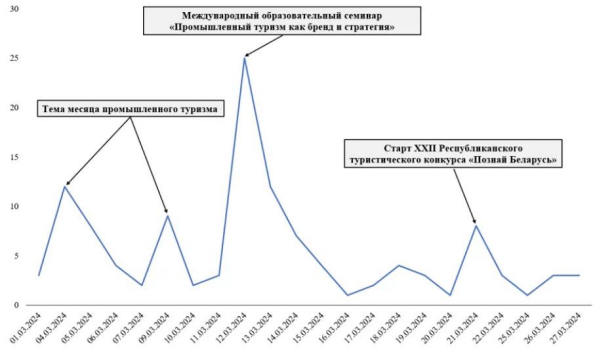

Рисунок.1.Динамика привлечении туристов к посещению предприятий

Примечание: источник [2].

Организации промышленного туризма в условиях цифровой трансформации позволяют исследовать различные аспекты создания виртуальных туров на промышленные объекты, использования технологий дополненной реальности для улучшения опыта туристов, изучения влияния цифровизации на экономические, социальные и экологические аспекты промышленного туризма, а также разработки методики устойчивого развития промышленного туризма в условиях цифровой

трансформации, включая минимизацию негативного воздействия на окружающую среду, сохранение культурного наследия и обеспечения социальной ответственности.

Цифровая трансформация в туристической сфере подразумевает стратегическую интеграцию цифровых технологий в процессе обслуживания посетителей и операционных процессов, что улучшает доступность и обеспечивает персонализированный опыт, который позволяет аудитории глубже проникнуть в культурный контекст.

Таким образом, использование цифровых технологий в промышленном туризме стало неизменным, что связано с потребностями клиентов. Выявлено , что именно клиенты все больше меняются в связи с использованием интернета для целей информации и бронирования. Следовательно, они влекут за собой корректирующие реакции со стороны туристических услуг, создавая технические и организационные предпосылки для цифровых технологий общения с клиентами. Установлено, что распространение цифровых технологий основано на соотношении затрат и выгод, поскольку эффекты рационализации могут быть достигнуты за счет стандартизации и централизации с помощью цифровых приложений.

Заключение.

Таким образом, установлено, что республиканский промышленный туризм является одним из факторов, обеспечивающих устойчивость пространственного развития регионов и повышающий имидж предприятий, позволяет потребителям увидеть процесс производства продукции, установить партнерские связи. Выявлено, что промышленный туризм позволяет посетителям увидеть индустриальную культуру и производственные процессы, предприятиям позволяет продемонстрировать инновационность и уникальный промышленный потенциал, а леверидж промышленного наследия позволяет создавать уникальные и конкурентоспособные туристические продукты.

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Анализ Пространственного Левириджа Организации Промышленного Туризма

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В статье проанализирован пространственный левиридж организации промышленного туризма, оценен потенциал его развития, предложена модель взаимодействия участников отрасли. В качестве методологической основы использованы методы анализа и синтеза, обобщения и классификации, моделирования. Информационной базой послужили нормативно-правовые документы Республики Беларусь (РБ), научные статьи, периодические издания в области промышленного туризма, методологии развития промышленного туризма, статистические сборники по исследуемой тематике. Исследование позволило оценить пространственную организацию промышленного туризма, взаимодействие участников промышленного туризма и комплексно подойти к его развитию, созданию системы обмена опытом в различных отраслях промышленности, определить ожидаемые результаты от развития промышленного туризма для его участников в республике.

Ключевые слова: анализ, пространственная организация, промышленный туризм, развитие, регион.

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Sustainable Development Of Education, Or Education For Sustainable Development?

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KEYWORDS

Education;

Sustainability;

Education management

ABSTRACT

The article explores the idea behind the sustainable development of education, which is to shift from the simple transfer of knowledge and skills necessary for existence in modern society to the readiness to act and live in rapidly changing conditions, to participate in shaping social development, to learn to foresee the consequences of actions taken, etc. The main challenge here is that organizational forms are once again being thought out, plans for activities to move from one level to another are being drawn up, but an internal plan that would allow tracking, directing and programming the work of psychological mechanisms (primarily those related to motivation and goal setting) is being overlooked. At the same time, education as a social institution plays an exceptional role in creating conditions for the sustainable development of society, ensuring the continuity of generations, replenishment of human resources, well-being, personal and professional development throughout life

INTRODUCTION

Education as a social institution plays an exceptional role in creating conditions for the sustainable development of society, ensuring the continuity of generations, replenishment of human resources, well-being, personal and professional development of a person throughout life.

On the one hand, education in all historical eras reflects the state of society in all its spheres: social, economic, cultural. On the other hand, global changes in the life of society cause changes in the education system, changing goals, tasks, content, organization and methods. Adapting to the demands of society, education performs its functions as a social institution.

Modern society is developing very dynamically, and this has an impact on education. The main factors influencing the development of world educational systems include globalization processes, the acceleration of social and economic development, the transition to a post-industrial society and knowledge economy. Globalization processes require modern education to develop students' internal mobility, the ability to adapt and be successful in any socio-cultural conditions, and readiness to improve in the professional sphere in accordance with new requirements and conditions of work and life. The acceleration of social development is highlighted by analysts as a global trend in the development of the world community, which is characterized by an increase in the volume and intensity of information flows, expansion of innovative processes, rapid scientific and technological progress, changes in living conditions, and dynamic economic development. Active economic development leads to increased competition at the global, national, and regional levels, a reduction in the scope of unskilled and low-skilled labor, profound changes in the employment structure, which, in turn, determines the constant need for advanced training and retraining of workers, and an increase in their professional mobility. In the context of the transition to a post-industrial, information society, the role of human capital is becoming extremely important. This is due to the fact that human capital is a system-forming element of the new knowledge-based economy, the importance of which is increasing every year.

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The main feature of the new modern conditions of social development is their direct impact on the cognitive and creative abilities of a person, necessary for obtaining and effectively using new scientific knowledge. A modern person lives in conditions of a high degree of uncertainty and must be ready to live in constantly changing conditions, possess such qualities as adaptability, mobility, constructiveness, creativity, the ability to quickly make decisions, the ability to navigate in the growing information flow. The formation of competencies necessary for sustainable successful development throughout life is a task that determines the essence and directions of development of modern education.

1.Sustainable Development Of Education: a Framework

Let us consider very briefly the framework for sustainable development of an individual's intellectual potential that we have proposed. The framework comprises several modules. This framework can be used when working with different groups: high school students, college students, and adults.

It is necessary to emphasize that the presented modules are not only work with a certain content, but also programs with a psychotechnical focus - they create a sense of success in the subject, provide interest in mastering vocabulary, and form stable motivation. Strategically, psychotechnics are aimed at:

A. “Launch” the mechanism of self-development and self-training of the individual.

B. Once launched, psychotechnics provide self-sustaining development.

C. The psychological technologies used ensure the expansion of the sphere of development and transfer to broader (compared to the initial stages) areas and spheres of life (for example, to the professional).

The framework we propose includes the following modules.

1. Language. The module is aimed at making a person aware of latent knowledge. The fact is that a person remembers much more than he/her realizes. In particular, he knows many words, uses them in speech, but does not fully understand their meaning. The module is aimed at making a person aware of this latent, implicit knowledge. Since the Russian language contains many words borrowed from English, French, German, Greek, Latin, Arabic, and Tatar, then understanding the meaning and origin of a word makes it possible to use the acquired knowledge. As a result, it turns out that a person actually knows hundreds of words from the above-mentioned languages. The implementation of the module begins with understanding the meanings of personal names and surnames, and extends to understanding words of the native language that have a foreign origin. As the subjects move through the module, their interest in etymology and the origin of set expressions increases. They become motivated to study foreign languages and literature in foreign languages. The exit from the module ends with the formation of an interest in languages and cultures. The further direction of development is connected with mastering foreign languages, a steady interest in studying the history of peoples and cultures.

2. Memory. Memory is considered as the foundation of human mental life, the basis of cognitive activity. The module is aimed at familiarization with the psychological patterns of memorization and reproduction, at mastering the technology focused on effective memorization based on active work with the material. The main purpose of the technology is that it makes memory manageable. Memory begins to work in the mode of semantic memorization, when memorizing, semantic processing of the memorized occurs, factors are used that increase the effectiveness of involuntary memorization. The meaning of the technology used is that the skill of logical text processing is automated and does not require any more control of consciousness. The effectiveness of memorization increases many times over. Since this is a technology, it is clear that its observance guarantees the receipt of a result, which, in turn, leads to the emergence of positive emotions, increased self-esteem and faith in one's own strength. The further direction of work on exiting this module is that the subject comes to the idea of reorganizing the structure of his knowledge, giving it a more rational form, streamlining knowledge systems and external generalizations. By carrying out a thematic reconstruction of knowledge systems, the subject inevitably turns to a revision of the systems of his professional experience and knowledge, that is, the scope of application activity is significantly expanded.

3. Understanding. As is clear from the previous sections of this article, understanding is considered the most important process in the structure of cognition. When mastering this module, students become familiar with the patterns and mechanisms of understanding. Particular attention is naturally paid to teaching the techniques of achieving

understanding, which presuppose a mandatory exit to the structures of the subject's experience. Learning these techniques occurs quite easily, since it is largely prepared by the results of the previous module, when the subject learns to be quite aware of the structures of his knowledge. It is especially important at this stage of the work to demonstrate to the students that there are levels of understanding. Sections are included that show the components of understanding associated with the collective unconscious. Understanding is also considered a necessary component of understanding existence; work on this module leads the subject to an understanding of ultimate meanings, awareness of terminal values and the meaning of life.

4. Thinking and creativity. This module is sometimes divided into two components: thinking and creativity. In this text, we will consider them together. This module involves familiarizing students with the patterns of thinking and solving thinking problems. Its content is based on the author's many years of research aimed at studying thinking activity and the difficulties of thinking. Psychological research shows that the most significant difficulty in the creative thinking process is not in finding the right hypothesis, the idea of a solution, as is often believed, but in overcoming the error recorded in the initial tacit knowledge, in the structures of subjective experience.

5. Personality. The last module is devoted to the development of personality, its main substructures. The main task of this module is to organize effective interaction of personality substructures, to promote the process of individuation, which continues throughout a person’s life.

2.Creative Process: Important Challenges

Since the most significant difficulty in the creative process is overcoming delusion, correcting the structures of subjective experience, then when teaching creativity, the emphasis should be placed precisely on this. When designing training programs, it is useful to consider that it is possible to construct a typology of difficulties of problems in the creative process associated with the structures of subjective experience, which in their origin can be individual (that is, formed as a result of the experience of an individual's interaction with the outside world) and “collective” (formed as a result of the assimilation of social experience). It seems appropriate to distinguish the following types of difficulties in the creative process:

A. The simplest (first type) difficulties will be those connected with the actualization of subjective experience structures that are irrelevant to the situation. The problem in this case can be easily resolved when the subject actualizes the experience structures that correspond to the situation. Many puzzle problems present precisely this kind of difficulty for the solver.

B. The second type of difficulties: the structures of experience actualized by the subject are inadequate (contain an element of delusion), but at another level of the structures of subjective experience the problem solver has adequate knowledge, and thus the correction of the structures of experience, overcoming of delusion and, ultimately, the solution of the problem is achieved due to the interaction of the structures of subjective experience of different levels and the correction of inadequate elements of experience that occurs during the thought process.

C. The third type of difficulties can be observed in cases where the subject does not have adequate structures at all, therefore the correction of the structures of experience can only occur as a result of a productive thought process (creative thinking in the strict sense of the word).

D. And finally, the fourth type: adequate structures of experience do not exist at all (neither for the subject solving the problem, nor for society), therefore the correction of structures of experience that occurs in the productive process leads to overcoming the error and the formation of new knowledge - both for the subject and for society (the so-called "great creativity"). Here it becomes clear that this process can sometimes take years, spent not on fruitless searches for an idea, but on overcoming those ideas that make it impossible to formulate the necessary hypothesis.

A particularly important and labor-intensive task in implementing this module are actions aimed at connecting unconscious mechanisms of creativity, which is achieved using the material of complex creative tasks. Prospects for going beyond this module include the use of non-standard and creative thinking in the professional sphere and communication (solving so-called creative communication problems). It can be assumed that the consistent implementation of the program modules can serve as a framework for organizing informal, psychologically based education.

Conclusion

As it can be seen from the text above, the subject of psychology appears to be the central problem not only of psychology itself, but also of pedagogy, which develops and designs the content of education. We have already drawn attention to the fact that within the framework of the architectonics of the inner world, the role of abilities, cognitive processes, motivation and personal qualities in solving educational problems becomes clear, which allows us to effectively organize psychologically sound training, solve problems of understanding, overcome other shortcomings in the formation of knowledge and experience, etc., both those noted above and others not specified in this text. Let us repeat that, in our opinion, both informal education and continuous education are very promising objects of research in the light of the interpretation of the subject of psychology as the inner world of man. Within the framework of the architectonics of the inner world, there is a place for the interaction of all types and forms of learning, in the context of the inner world, it becomes possible to track the accumulation of experience of various origins and ensure the continuity of its generalization in the context of sustainable education.

Issues related to changing the interpretation of the subject of psychology are usually perceived as a kind of revolution. Let us note that in our case nothing of the sort is happening: no manifestos, no overthrows are envisaged. Moreover, the interpretation of the total subject as the inner world of man emphasizes its integrity, but asserts the presence of various heterogeneous structures in the inner world. Thus, the fundamental thesis is asserted that the inner world of man is a complex formation. At this point, the formulated approach means a categorical break with the tradition that, at least since the Middle Ages, has asserted that the soul (psyche) is a simple thing that knows itself and other things. Surprisingly, psychological schools and trends, including modern ones, have followed this ancient, but highly controversial teaching. From here, by the way, it follows that it is implicitly assumed: the method of study should also be simple. We also think this is a misunderstanding and an anachronism: it is obvious that the world is complex, and therefore the methods of its study are different - depending on what part of the world is being studied. Therefore, when speaking about methods, it is worth emphasizing that most often we are talking about a complex of methods, their combination. In other words, methods are used both from the arsenal of natural-scientific psychology and from the range of hermeneutic methods.

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Digital Logistics As a Factor In Enhancing Industrial Competitiveness: a Comparative Analysis Of China And The Republic Of Belarus

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KEYWORDS

Digital logistics;
Industrial competitiveness;
Digital transformation;
Republic of Belarus;
Industry 4.0;
International cooperation

ABSTRACT

The purpose of the study is to determine the role of digital logistics in enhancing the industrial competitiveness of China and the Republic of Belarus. The research employs systemic, institutional, and innovation-oriented approaches, as well as comparative analysis. The study shows that China is pursuing a strategy of technological leadership and actively introducing innovations into logistics, whereas Belarus is establishing the institutional foundations for digital transformation while expanding international cooperation. The digitalization of logistics increases the efficiency of supply chains and strengthens the competitive advantages of both economies. The results obtained can be used in developing digital logistics strategies and innovation development programs.

ВВЕДЕНИЕ

Мировая промышленность в условиях цифровизации требует модернизации производственных и логистических процессов. Цифровизация — ключевой фактор устойчивого развития и формирования конкурентных преимуществ национальных экономик [1]. Одним из её основных элементов является цифровая логистика, объединяющая инновационные инструменты управления потоками и повышающая эффективность цепей поставок.

Для Китая и Беларуси цифровизация имеет особое значение. Китай реализует государственные инициативы в рамках стратегий «Индустрия 4.0» и «Цифровая экономика Китая», направленные на трансформацию промышленности и внедрение технологий искусственного интеллекта, больших данных и Интернета вещей [3]. Беларусь рассматривает цифровую логистику как инструмент интеграции в глобальные производственно-транспортные сети, укрепления экспортного потенциала и снижения издержек.

Сравнение опыта двух стран позволяет выявить взаимосвязь между уровнем цифровой зрелости логистических систем и конкурентоспособностью промышленности, а также определить направления формирования эффективных моделей цифровой трансформации.

1.Методологическая База Исследования

Методологическая основа — системный, институциональный и инновационно-ориентированный подходы.

Системный подход рассматривает промышленность как комплекс подсистем — производственной, логистической, кадровой, финансовой и информационной; цифровизация логистики связывает их, обеспечивая синхронность движения ресурсов и оптимизацию управления.

Институциональный подход изучает механизмы, влияющие на темпы цифровой трансформации, позволяет выявить различия в моделях регулирования Китая и Беларуси и оценить влияние институциональной среды на инновационную активность предприятий.

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Китай реализует стратегию технологического лидерства, развивая инновации и цифровые экосистемы, тогда как Беларусь формирует модель цифровой трансформации, опираясь на институциональное укрепление и международное сотрудничество [3].

Для достижения цели применяются методы сравнительного анализа и обобщение статистических данных о состоянии цифровой логистики в двух странах.

2.Аналитическая Часть: Текущее Состояние Цифровой Логистики в Китае и Беларуси

Развитие промышленности Китая и Беларуси показывает различие в уровне цифровой зрелости логистических процессов. В Китае цифровая логистика — ключевой элемент стратегии экономического развития. Созданы национальные платформы, объединяющие производителей, поставщиков и транспортные компании в цифровую экосистему. Компании используют прогнозирование спроса, интеллектуальную маршрутизацию и автоматизированные склады, что повышает эффективность цепей поставок. Государственная поддержка выражается в налоговых стимулах и грантах, способствуя цифровизации не только крупных корпораций, но и среднего бизнеса.

Беларусь при меньшем масштабе экономики стремится к модернизации. Реализуются программы развития цифровой инфраструктуры, включая индустриальный парк «Великий камень» [4]. Сохраняются проблемы — износ фондов, низкая автоматизация и нехватка ИТ-специалистов.

Доля цифровых решений в логистике составляет около 70% в Китае и 35% в Беларуси. Китай демонстрирует масштабное внедрение интеллектуальных систем управления цепями поставок, тогда как белорусская модель развивается точечно. Беларусь имеет потенциал ускоренного роста благодаря выгодному географическому положению [7], участию в интеграционных объединениях и стабильной правовой базе.

3.Основные направления повышения конкурентоспособности промышленности

1. Цифровизация логистических и производственных процессов

Внедрение технологий Интернета вещей, искусственного интеллекта и цифровых двойников является ключевым направлением. Китай применяет эти инструменты для анализа производственных рисков и планирования мощностей, а Беларусь может адаптировать опыт, создав национальную систему цифрового мониторинга логистики, обеспечивающую прозрачность поставок и эффективность транспортных операций [5].

2. Развитие инновационной инфраструктуры

Отраслевые логистические центры, технопарки и лаборатории прикладных исследований создают условия для тестирования решений и интеграции научных разработок в промышленную практику. Совместные китайско-белорусские проекты способствуют формированию цепей добавленной стоимости [6].

3. Институциональные стимулы и государственная поддержка

Государственная политика — катализатор цифровых преобразований. Китай применяет налоговые преференции, финансирование стартапов и «регуляторные песочницы», а Беларусь совершенствует нормативную базу и снижает административные барьеры, формируя благоприятный инвестиционный климат.

4. Развитие человеческого капитала

Подготовка кадров — основа устойчивого развития цифровой экономики. Китай реализует образовательные программы в области логистики и управления инновациями, Беларусь внедряет дуальные программы и курсы повышения квалификации. Совместные инициативы университетов формируют базу для реализации концепции «Индустрия 4.0».

5. Международная кооперация и обмен технологиями

Сотрудничество объединяет технологический потенциал Китая и транзитные возможности Беларуси. Совместные инициативы в рамках «Пояса и пути» и ЕАЭС способствуют созданию трансграничных цифровых коридоров и росту экспортного потенциала [3].

6. Переход к устойчивой и «зелёной» логистике

Принципы ESG — важный элемент промышленной политики. Китай внедряет экологические стандарты в транспорт и энергетику, а Беларусь использует этот опыт для развития зелёных коридоров, повышения энергоэффективности и применения возобновляемых источников энергии [2].

ЗАКЛЮЧЕНИЕ

Исследование показало, что цифровая логистика — ключевой инструмент повышения конкурентоспособности промышленности Китая и Беларуси. Цифровизация логистики повышает эффективность цепей поставок, прозрачность управления и устойчивость производственных систем, формируя основу технологического развития экономик [6].

Китай реализует стратегию технологического лидерства, развивая инновации и цифровые экосистемы, тогда как Беларусь формирует модель цифровой трансформации, опираясь на институциональное укрепление и международное сотрудничество[3].

Дальнейшее повышение конкурентоспособности промышленности обеих стран определяется скоростью интеграции цифровых технологий, готовностью кадрового потенциала и развитием инновационной инфраструктуры[5]. Значение имеют цифровые и «зелёные» проекты в рамках инициатив «Пояс и путь» и ЕАЭС, способствующие созданию трансграничных цифровых коридоров и укреплению устойчивого роста.

Результаты исследования могут служить основой для разработки стратегий цифровой логистики и совершенствования инструментов государственной поддержки инноваций. Системная цифровизация логистики — стратегический фактор укрепления конкурентных преимуществ Китая и Беларуси на глобальном рынке [6].

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Цифровая Логистика Как Фактор Повышения Конкурентоспособности Промышленности: Сравнительный Анализ Китая и Республики Беларусь

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Цель исследования — определить роль цифровой логистики в повышении конкурентоспособности промышленности Китая и Республики Беларусь. В работе использованы системный, институциональный и инновационно-ориентированный подходы и сравнительный анализ. Исследование показало, что Китай реализует стратегию технологического лидерства и внедряет инновации в логистику, тогда как Беларусь формирует институциональные основы цифровой трансформации, развивая международное сотрудничество. Цифровизация логистики повышает эффективность цепей поставок и укрепляет конкурентные преимущества экономик. Полученные результаты могут быть применены при разработке стратегий цифровой логистики и программ инновационного развития.

Ключевые слова: Цифровая логистика，конкурентоспособность промышленности，цифровая трансформация，Республика Беларусь，Индустрия 4.0，международное сотрудничество.

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The Literary Norm In The Grip Of Dogma And Dialectics

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KEYWORDS

Literary language;

Norm principles of norming dogma;

Dialectics

ABSTRACT

In modern linguistic literature, the need to combine statics and dynamics in the literary norm is beyond doubt, on the basis of which the idea (so far only the idea) of creating principles for the regulation of innovations is put forward. The article examines the issue in historical terms on the material of the Armenian and Russian languages, taking into account the fact that the literary language is a national language that has certain rules of use. Its formation, according to the author's approach, goes through four stages: the folklore stage, the written language, the literary version and the canonized version. Its development can begin on the basis of its own dialects or by crossing languages, on the basis of the spoken language of not only the political, but also the cultural center, proceed permanently or abruptly. In any case, the normative layer of the literary language is formed on the basis of oral speech and finds expression in the language of outstanding writers who make their own adjustments related to the strengthening of expressiveness.Changes in the language are divided by the author into formal and substantive. At different periods of language development, some tendencies intensify, others fade. At the present stage, formal changes (phonetic, grammatical) are passive, since the dialect base of both Armenian and Russian languages has not changed over the past two centuries, and substantive changes have intensified due to the development of figurative thinking. Both in the first and in the second case, the changes are due to colloquial speech, therefore, according to the author, before developing the principles of standardization of the literary language, it is necessary to determine the directions of development of colloquial speech. The dependence of language development on the development of society excludes the development of accurate methods for determining the literary (normativity) of language transformations and makes the boundaries of the literary language quite transparent, which is why there is no convincing theory of its development. Excessive freedom leads to the blurring of the boundaries of the norm, and excessive conservatism leads to crises, as was the case with the ancient Armenian literary language (Grabar), which is why the construction of a new literary language begins.

INTRODUCTION

The literary norm is always dominated by dogmas and dialectics. Currently, the desire for state regulation of language norms is increasing, and the purpose of this article is to establish whether it (state regulation) can have significant consequences in the history of the literary language and whether the canonization of norms can stop their violations. These questions can only be answered by the history of the literary language, in this case – Russian, which is given in a comparative description with the history of the Armenian literary language, since the conditions of formation of the latter are directly opposite to the conditions of development of the first, and if the construction of the language depends on the official rules, this can be reflected in the history of at least one of these languages.

In modern linguistics, a literary language is understood as a language recognized as common to the entire ethnic group - the language in which all national literature (including administrative documentation) is created, having clear rules of use, designed to serve several dozen generations. In view of this, following the modern literary norm, established

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rigidly and definitely, mandatory at the highest state level, is a necessary condition for the creation of national texts (speeches in the media, scientific papers, textbooks and educational materials; fiction, mainly, etc.), which corresponds to their purpose and functions. This is well known, and there is no point in quoting any "luminaries" in this area. At the same time, the literary language (and, accordingly, the literary norm) functions in time and space. The requirement to strictly observe literary norms, their stability, is a dogma, in another interpretation, dogma means "to stop time", which contradicts the very essence of dialectics. "... In the norm of language, the historically educated common usage of language means is noted, as well as the rules for their selection and use, recognized by society as the most suitable in a particular historical period" [30, pp.18-19]. The issue of "conservation" of norms is quite clear: "The written tradition constrains the process of linguistic changes" [13, p.80], "the measure of the constancy of language is the circumstances that change the chances of stimuli for the emergence of some statements and the disappearance of others" [13, p.81]. At the same time, the dialectical process of development constantly updates the means of the literary norm: "it would be wrong to think that the literary norm is stationary: it develops and changes over time" [9, p. 13; etc.], but how to establish approaches to the assessment and formation of these changes? What can and cannot be changed? A dead end situation arises: the requirement to strictly observe literary norms, since the literary language must serve the entire ethnic group in several of its generations, comes into conflict with its dialectical development. This is the first thing. Secondly, there are certain normative rules, but there are no rules for their normalization, recognition of a phenomenon in the sphere of the norm or outside it. It would seem natural that "it is the duty of scientists not to passively state what is happening, but to determine the focus of what is needed and what is "not necessary" for the language, make forecasts and recommendations, instead of geological and topographic maps of the linguistic district, invent a reliable linguistic compass" [14, p.10], but according to what principles it should be is it formulated and how should it be? It seems logical that, "asserting their right and ability to influence the language, even the obligation to regulate it in the name of national-state unity of society, for the sake of education, discipline and order in it, people are obliged to know the boundaries of what is permissible" [14, p.13], but how to outline them?

Materials and Methods

The formation of literary languages goes through several stages. Initially, the language that functions as speech for a small mass of listeners was the language of folklore. This is the first semblance of a mass media outlet. The study of samples of ancient Armenian and Russian folklore seems to indicate the development of a special style of songs and legends in them. We emphasize "as if", because folklore works have been collected and published at best since the middle of the nineteenth century and, naturally, during the period of "oral existence" they were constantly processed. Since dialects do not develop outside of contact with other dialects (grammar and phonetics do not change much) [16], the functioning of the "mass" style with the dialect speech became the beginning (albeit qualitatively and quantitatively insignificant) of the formation of a national language.

Writing in the Armenian and Russian areas appeared with the adoption of Christianity, the first and most powerful factor of conscious national unity. A spiritual text can really be called the beginning of understanding (perception) of some forms and expressions as exemplary (from a political point of view – consolidating).

The first Russian texts, as is known, were created in ancient Bulgarian, since Christianity in Russia spread from Byzantium. It was different from colloquial, actually Old Russian. This is an example of an external source of the written language. There was no rigid unity in the rules of writing, although the desire to adhere to the language of sacred texts was obvious. In our opinion, the style of the spiritual work is perceived as high. The opposition of two types of speech begins. Oral speech turns out to be beyond limitations, while written speech is characterized by obvious conservatism (it was necessary to follow the patterns clearly).

This situation is very similar to the one that is currently developing in connection with the canonization of literary norms, moreover, the spiritual text was sacred, which for the scribe meant blind adherence to tradition, but the samples were still violated.

If we compare the monuments of the period of the Vladimir Principality, on the one hand, and ancient Novgorod and Pskov, on the other, it is difficult to deny that their language is oriented towards the language of spiritual texts (Old

Slavic, Old Bulgarian). This has been proven in more than one scientific work from the beginning of the last century and the century before last (and maybe even earlier). At the same time, the linguistic features of these monuments are explained by the influence of the living spoken Russian language of the territory, i.e. the corresponding urban koine, in the area of distribution of which they were created, therefore, their language often varies from text to text. At the same time, this language is beginning to acquire one of the signs of a literary one – nationwidity.

In the Armenian written tradition, Western Armenian became the language of spiritual texts, since the center of cultural life at the beginning of the 5th century (when the Armenian alphabet was created, the Bible was translated) was located in Western Armenia. This fact clearly contradicts the well-established theory that the basis of a literary language can only be the language of the political center (and the political center was located in Vagharshapat, in Eastern Armenia).

Science does not have any facts that would allow us to call the language of the beginning of the Armenian writing in any way processed. We assume that he was no longer based on the language of a separate dialect or separate dialects (the Ayrarat and Taron regions of the central part of historical Armenia, as is customary in Armenian science), but on the folklore tradition of these territories. This is justified by the fact that it does not completely coincide with any of the Western Armenian dialects, it absorbs elements of several dialect groups. The process of actively integrating the Armenian language into scientific and political circulation has begun. The appearance of historical and philosophical writings was the second step towards generalizing the rules of writing letters and words, even in several variations. Libraries were created at the princely estates, universities, where education, of course, focused on spiritual literature. The Armenian language, divided into 44 small dialects from the Caspian Sea to the Aegean, in close contact with other languages of Asia Minor, preserved its national identity. This is an example of the internal development of a language becoming nationwide.

This period of the formation of literary languages we can call the language of writing, since writing is functionally and geographically limited and does not have all the features that allow the language to be called literary. It can also be called the period of the language of spiritual literature, historical chronicles, the beginning of accounting, the first examples of artistic creativity, etc., but not the literary language.

In Russia, the development of the national language was constantly going on through permanent changes in written speech under the influence of the spoken element [34, p.208] or by "editing" the spoken text under the influence of spiritual (exemplary) writing [38, p.183-184], which in any case should be considered as a crossing of two language systems: Old Bulgarian and Old Russian. Russian was developed in both directions in principle: the first way became the basis for the formation of scientific, and the second – business Russian speech [16]. It is surprising that the process of forming a literary language is considered very mechanistically: "Literary norms are formed over the long history of the language: the most commonly used ones are selected from national linguistic means, which in the minds of speakers are evaluated as correct and obligatory for all" [9, p.13]. This statement is a fiction, because it is difficult to understand how the consciousness of the speakers (which ones? The intelligentsia? Peasants? nobles?) selects "the most commonly used ones from the national linguistic means", according to which principle, not to mention the fact that it is impossible to accurately outline the boundaries of "what is allowed and what is not allowed" during this period.

If we keep in mind that literary language is a generalization of oral and written speech, processed by writers and focused on the language of a certain (exemplary) author(s), then written language goes its way to the literary version through hundreds of works of fiction. The Russian intelligentsia recognized the language of A.S. Pushkin as an exemplary one (without selecting only expressions "correct and obligatory for all"), which was created before him by the efforts of M.V. Lomonosov, N.M.Karamzin, V.A. Zhukovsky, etc. It is quite natural that Pushkin, like all other authors, chose expressions not "the most common", "correct and obligatory for everyone", but the most expressive from his point of view, which turned out to be really expressive. In other words, the formation of the Russian literary language proceeded by crossing the written and oral languages of that period (in different "shares") due to the educational activities of individual outstanding writers (not scientists!), naturally, step by step moving towards a variant that became nationwide, generalized. The language of A.S. Pushkin was recognized as such spontaneously, due to its quality.

From the second half of the XVIII century, grammars began to appear (M.V.Lomonosov, before A.S. Pushkin, then N.

Grech, etc.), which the creators of fiction and historical literature, as well as official texts, focused on, but they were not mandatory (official!), differed in their rules, although the written language began to acquire its second main feature is systematization, orderliness in the rules. Compare, declension of nouns and pronouns in V.V. Lomonosov's "Russian Grammar" (1755) [15] and N.I. Grech's "Extensive Russian Grammar" (1827) [11], between which there are only 70-odd years. N. Grech identifies 6 types of verbs, which he calls pledges [11, p. 243], Lomonosov has three voices: real, passive, and average, and the differences of the latter two are not due to the forms of the verb [15, p. 35]. Lomonosov distinguishes the indicative, indicative and indefinite moods [15, p. 34], while Grech indicates the indicative, imperative and subjunctive, however, without distinguishing the latter into a separate type: "In the Russian language, these forms (of the subjunctive mood. – V.M.) of verbs are expressed by the past tenses of the indicative with the addition of conjunctions бы, чтобы, дабы, да (to, in order, yes) etc." [11, p.249]. In these grammars, the literary norm becomes, as it were, a "harmonization" of the rules of oral and written speech, although from the point of view of modern linguistics none of the classifications consistently corresponds to the currently applied principles of distinguishing grammatical categories: neither unity of content and form, nor oppositivity. By presenting the grammar of a language, it seems to us that we reflect what is real. In fact, we "put" on the tongue the "shirt" that seems more appropriate to us. But is it such a thing?

M.V.Lomonosov's grammar does not contain those syntactic constructions (cripples) that N.Karamzin and then Pushkin introduced into the Russian language in order to create more expressive means (out of French) [38, pp.49-53]. Only the work of N. Karamzin and A. Pushkin can be spoken of as the "selection and use" of some linguistic means, but these are "recognized as the most suitable" not by society, but by creative personalities, and means very limited in scope, but, we repeat, necessarily exclusively expressive. Pushkin in Russia is considered the founder of the literary language, not because he introduced new morphological forms into use, but because he spoke in a more expressive language. In the "Grammar" of Lomonosov, in the creation of many numbers, only endings are recommended, which are considered normative and in the infusion currently, although in the same work "The letter G is pronounced in different ways" («Буква Г произносится разными образы») (our italics – V.M.) [15, p.48]. Here, the specified form is not stylistically highlighted. Pushkin, on the other hand, uses the ending –ы of ablative Pl. as an expression of the "cloth" style, i.e. as a means of enhancing the expressiveness of the text. Compare. in "Dubrovsky" in the court's ruling: «сенными покосы, рыбными ловли» (hay mowing, fishing). After Pushkin, the Russian literary language was processed by M.Y. Lermontov, N.V. Gogol, and others. Thus, it can be summarized that the formation of the literary language in Russia took place consistently.

A different situation developed in Armenia due to its loss of independence in the tenth century and its division between neighboring powers - Byzantium (then, from the XV century. - Ottoman Turkey) and Persia (subsequently, from the beginning of the XIX century. – the Russian Empire). The need to preserve national unity in the absence of their state authority required strict adherence to exemplary spiritual texts (Grabar), especially since in the current situation the church played a mobilizing role not only in spiritual terms, but also in law (Armenians did not sue in state sofas, but by the leaders of their religious community). Up to the beginning of the XIX century all Armenian literature (spiritual, historical, artistic, educational, scientific) was created only in the ancient Armenian language at church schools and in church libraries (since the middle of the fifth century, by order of the tsar Pope, monasteries in Armenia were liquidated). And, despite the rich literature in Middle Armenian, only the Grabar texts were recognized as exemplary. The changes concerned only vocabulary, while phonetics, morphology and syntax mostly strictly adhered to the standards of spiritual writing.

The entire XIX century for the Russian literary language, it is the age of its processing and perfection by self–regulation, naturally, on the basis of the conversational element. Each author offered his own individual style of presentation, based on the principle of expressiveness. Compare, for example, the styles of I. Turgenev and N. Leskov, Feta and N. Nekrasov.

With the establishment of Soviet power, the Russian language acquires the status of a literary language, which is why the trends of its ordering are increasing. Official institutions (commissions) define clear grammar rules, and those that do not meet the requirements of the time are removed from the old rules. These are not only transformations in the alphabet, but also in spelling (they took place all the time). The latter are considered to be the

"Rules of Russian Spelling and Punctuation 1956") [1], which are mandatory for school education and official speech throughout Russia. Several academic grammars of the Russian language have been published. However, it is enough to compare two school textbooks of the Russian language, as the differences in the interpretation of not only literary norms, but also spelling norms turn out to be obvious. This process is the process of defining literary standards based on spontaneously established traditions, rather than developing them (!).

Transformations in the Russian literary language during the twentieth century are scientifically substantiated in the works of the USSR Academy of Sciences. The authors emphasize not only the movement towards the systematization of linguistic facts, but also the influence of external components, such as the development of society, the impact of world languages, the spread of literacy (orthography) on phonetic transformations, etc. [26, pp.104, 112, 121; 27, p.10, 13].

It is difficult to state strict observance of the norms of the literary language when in Soviet society the Russian language not only changed "internally", but also acquired new types of word formation (for example, abbreviation, semantic contraction), new types of names (for example, compound names) [28, p.10]. Some of the processes observed at the end of the XIX century continue (the complication of consonantism, etc.) [27, p.10]. It is also necessary to add an extension of the usage speaking a literary language, in connection with which elements of other dialects penetrate into the latter, i.e. The entire Russian ethnic group is being involved in the work and processing of the literary language of the nation.

Only the stability of the morphological system is emphasized [29, p.9, etc.]. However, if we use the data from «Ведомости» (“Vedomosti”) for 2020 [36], the use of variable forms such as лошадьми (by horses) is sharply reduced (only forms that do not have "correct" analogues are consistently used – людьми, детьми - by people, children). There is a further consistent development of the literary language, due to the presence of the Russian ethnic group of its independent statehood.

To the outstanding Armenian educator Kh. Abovyan had to take the liberty and abruptly switch from Grabar (spiritual Armenian script) to Ashkharabar (spoken Armenian) due to the fact that the lack of permanent development led to a sufficient separation of the national literary language from the living, spoken one. Abovyan began with his own dialect, not thinking at all about the norms. The connection of traditions was broken. Attempts have begun (and successful ones!) creation of a new national literary language. Some writers began to process Grabar under spoken language (Muratcan) or spoken language through Grabar (Raffi). After establishing the rules of grammar (morphology), consistent work on expressiveness began (H. Tumanyan, V. Teryan).

This development should be called revolutionary. The history of society has made itself felt again in the history of language. In Eastern Armenia, which is part of the Russian Empire, the Eastern Armenian literary language began to form (classical works by Raffi, Shirvanzade, Muratsan, etc.). It turned out to be common in cultural centers that worked in the same legal and territorial plane (Yerevan, Tiflis, Baku, Shushi). Being processed at the end of the XIX – in the first half of the XX century by D. Demirchyan, H.Tumanyan, and finally by V. Teryan, with the establishment of Soviet power, it was ordered in its rules and recognized as nationwide and official, i.e. literary. In the cities of Arzrum, Van, and finally in Constantinople, the Western Armenian literary language was formed. After the Armenian Genocide in the Ottoman Empire in 1915, it now functions in all Armenian diasporas and still does not have unified rules of use. The difference in the lexical composition of the Western and Eastern Armenian variants of the Armenian language is insignificant, but the grammar is based on different dialect groups (the so-called k-dialects and um-dialects).

In the history of the new Armenian literary language (in its variants), the same patterns are observed as in the development of the Russian literary language: words and word forms that have fallen out of use are gradually replaced by spoken ones (compare, the language of Muratsan, on the one hand, and Raffi, Shirvanzade, Nar-dos, on the other), the rules of use are unified but, unlike the Russian counterpart, not only on the basis of the koine of the political center, but taking into account the expressiveness of similar forms functioning in different dialects (compare the languages of H.Tumanyan, E.Charents and V.Teryan).

The legality of creating two variants of the Armenian literary language instead of a single Grabar is still considered controversial, since they split the people to a certain extent. If we take into account that before the revolution of 1917, Armenians received primary education in their parish schools, and then only transferred to gymnasiums, with the adoption of new versions of the national language, school

programs in the Armenian language began to differ: the dogma had obvious positive sides. At the same time, remaining in the grip of dogma meant for the majority of the population to remain outside of live oral and written literary speech. Dialectics had to be taken into account: the literary language, since it was national, had to be understandable to the whole people.

During the Soviet period, work began on the normalization of the Armenian language (after all, before that period the process was spontaneous!) – and quite successfully. Moreover, the question concerned not only the speech of the peoples who had a written language (Russians, Ukrainians, Belarusians, Armenians, Georgians), but also the speech of non-written peoples (Volga and Azerbaijan Tatars, Kirghizs, Kazakhs, Turkmens, etc.), for whom alphabets had been based on the Russian alphabet, literary norms had been focused on the spoken language of the political center. These norms have been fixed both in political documents and in educational and scientific literature [40]. The formation of these literary languages can also be considered a revolutionary (by leap), but it was carried out by generalization of linguistic facts by linguistic scientists, and not by official decrees.

From this period, we can talk about literary languages proper, since they acquired all the above-mentioned signs of literariness.

In the post-Soviet period, Armenian and Russian literary languages received the status of state languages, which required the final consolidation of the norms of use, for violation of which by officials, the Russian government established, as indicated above, the appropriate punishment [5]. The Armenian government has formed a special committee to monitor the correct use of the Armenian literary language (including in the speeches of officials). The transition from a standardized literary language to a codified one means a ban on violations of established norms in a natural way, officially generalized by scientists. The concept of speech culture has finally been formed. Along with this, the richest Armenian and Russian linguistic literature of the twentieth century, as well as the literature of other nations, recognizing the need to follow legalized rules, recorded violations of them [4; 26]. Moreover, grammar was considered and is considered to be normative first of all. Borrowing, the appearance of new meanings in words are issues that previously did not cause any special objections, although the use of a word or phrase, syntactic construction outside the literary norm is also a violation of the culture of speech. These processes, as noted, are permanent and are associated with both the development of society and the development of intercultural and interethnic ties [18, pp.7-14; 19, pp.57-68].

Does codification mean the status quo in the development of the language, or does it still have the right to change? Which ones? So - if we state the development. It is clear that [д’в’ёр’] during the twentieth century and now passes into [дв’ёр’], but what is considered correct, literary? How is it "legal" to pronounce [дэка́н] or [д’икан] so as not to violate the "state" etiquette of speech culture and not be officially fined? If we proceed from the well-established opinion that certain forms or words, the meanings of words are initially considered violations of norms and are recognized as literary only with a high frequency of use, it is necessary to recognize the admissibility of such (which?) errors. "I don't like Russian speech without a grammatical error," the great Pushkin joked. This is at the grammar level.

In the last years of Soviet rule, there were constant disputes in Armenian linguistics about the recognition of a particular word as literary or non-literary. In particular, an example of the word թոռ [thor] (meaning "seine") was given. In reality, neither side had a solid basis for evidence. The only criterion is the frequency of use in normative speech, which is the official press, as has long been accepted in our linguistics. And what should the official press be guided by?

It would seem that the development of literary Armenian and Russian languages shows that the codification of norms leads to a slowdown in the pace of phonetic and morphological changes, while – regardless of state regulation - lexical and semantic transformations continue, which is associated with the development of society, public relations, and the development of abstract thinking [17, pp.62-73]. The language is moving towards increasing expressiveness, to combining semantics and stylistics ("two or three in one"). Figurative words and expressions appear in the unofficial press that are completely unrelated to street, obscene language: давить подушку (to crush a pillow = "sleep"), колбасить (to be sausage = "clumsily, drunkenly dance"), etc.; words acquire new meanings, without violating the general rules of semantics development at all: бригадир (brigadier = "leader of a criminal group") and others. In the middle of the last century, linguists did not allow too abstract transfer of meanings. "... "Wooden table" and "table of wooden" are possible, but "wooden smile" and

"smile of wooden" are impossible," wrote Z.S. Harries [12, p.554]. In modern English, wooden smile is quite possible, although it may be more occasional or in a stylistically colored text.

The reasons for the slowdown in phonetic and morphological transformations of the languages under consideration are explained rather not by the codification of norms, but by the stability of their dialect base over the past two centuries. There are no significant changes in the spoken language, so there are none in the literary one. In the specified grammars of Lomonosov and Grech, with the exception of some verbal formations: participles of the type двиганъ (moved) [15, p.133] adverbs of the type двигаючись, парючи (to be moving, to be soaring) [15, p.138], forms of the past tense [15, p.129-132, etc.], paradigms of declension of words сорок, девяносто, сто (forty, ninety, one hundred) [15, p.102-103] and some others, which are hardly rigidly connected with live use, the morphological system of the Russian language still functions in an almost static form.

A special topic in modern official documents is the use of borrowings. G.O. Vinokur believed that "word–making" (in this case, purism) is meaningless when there is a possibility of borrowing [39, pp. 163-173]. "But pantaloons, tailcoat, waistcoat – All these words are not in Russian. Shishkov, I'm sorry, I don't know how to translate," Pushkin confessed. F.P.Filin, on the contrary, demanded the use of the internal capabilities of the Russian language [8, p.15-61].

These questions are theoretical problems that modern linguists should solve in order to answer the practical questions of time. To paraphrase K. Marx, we note that modern linguistics is working on ways to describe a language, while it must also work on how to improve it and protect it from tabloidism, how to permanently normalize it so as not to tear the literary language from the living. For centuries, the words жопа, говно (ass, shit), which were considered non-literary, obscene, suddenly turned out to be equal members of the Russian lexical "society" [21], along with задница, испражнения movements, although it is quite clear that they mean the same thing and we are talking only about the tradition of use, and, strictly speaking, it does not matter at all how these objects are to name. But what about “Dictionaries of Russian words outside of Russian Dictionaries”? [25]. These have been published from time to time abroad, fixing Russian tabloid jargon. What is the value of them? When is it possible to break tradition, cross the "red line" in vocabulary? There are no standards for this at all, although there are many attempts to create standards [3, pp.91-101].

If the development of a literary language is determined by a spoken one, then it should be recognized that at present the norms are established by scientists by the inductive method, by general conclusion. If we admit that the literary language is processed by the intellectual efforts of individual writers (and it is), we state that the literary language is artificial in terms of rationing, although neither Pushkin, as already indicated, in Russian, nor H.Tumanyan or V.Teryan in Armenian were introduced into the language, for example, new forms and paradigms of declension. When we establish certain rules of use at the level of codification, which today we call the culture of speech, it means that we recognize that these rules are artificially systematized based on the natural development of language. In this case, the issue of rationing, the establishment of a norm, is a matter of ascertaining natural progress. If it were possible to identify ways to establish certain norms, generalizations could be made. So, there was a музы́ка (from Poland. muzýka, in Polish, the stress is always on the penultimate syllable), which was replaced by a му́зыка. Similar transformations have been experienced by физика, лирика, мимика, паника, техника (from Polish. fizyka, liryka, mimika, panika, technika), etc. This happened under the influence of transformations in the speech of society. Why and based on what the norm was transformed? Today's linguistic "toolkit" does not allow us to draw any convincing conclusion, which is no longer needed as a historical fact, but as a method for orientation in the development of language in the future, since the level of language development is the level of linguistic thinking, and the latter is the basis of national security.

Russian scientists noted the growth of agglutinativity in the semantics of a derived word, the increase in the number of suffix morphemes with a single content etc. by the middle of the last century. In terms of word formation, the process of Russification of non-Russian suffixes is quite active in modern Russian, i.e. the inclusion of non-Russian suffixes in the word-formation processes of the Russian language. Compare, along with большевизм, меньшевизм (bolshevism, menshevism), also chiefdom, отзовизм, украинизм, пушкинизм, милитаризация, славянизация, бумаженция etc. (otzovism, ukrainism, pushkinism, militarization, slavianization, paperwork) [41]. Morphologically, the number of non–declinable nouns is increasing, and - mainly of the middle gender, nouns of the

so-called general genus (two-gendered): бойфренд, бизнес-вуман (boyfriend, businesswoman) etc. Last examples indicate a weakening of the gender category in the literary language, which, according to S.P. Obnorsky, is very actively reflected in dialects already at the beginning of the last century [20, p.217]. Some borrowings have only one form – Nominative (boyfriend, businesswoman). The "Russification" of borrowings is very active, especially in colloquial speech, their inclusion in the Russian inflectional paradigm (primaries, restyling, biopic, etc.). This is a tendency towards uniformity of expression. "If the free combination of linguistic elements produced by an individual did not coincide with the vast majority of cases with the traditional form, then the development of language would be difficult" [5, p.14]. Russian Grammar is only ten years old between the "Grammar of the modern Russian literary language" [10] and the "Russian Grammar" [23; 24], but in the latter, for example, there are syntactic constructions of the type Видно следы (Traces are visible), about which there is no information in the first grammar.

These changes occur in spite of themself of linguistic scientists, who can only arrange them to derive general rules.

Borrowing is a natural result of the mutual influence of languages, but in connection with political, scientific, and economic revolutions, their influx should be restrained (how?). There are many borrowings in modern Russian and Armenian languages related to the spread of new technology. They enter the literary language in borrowed (in Russian) or calcified form (in Armenian), regardless of the requirements of the literary norm (which one?). F. de Saussure within the specified (but only!) is right: "Language activity is not regulated by any human norms; the human mind cannot constantly correct and direct it and does not do so" [32, p.97]. When we assert that language policy is "a system of measures of conscious regulatory influence on the functional side of language, and through it, to a certain extent, also on its structure" [2, pp.28-29], we can only mean language construction as a state phenomenon, the principles of language use in some society – at the level of sociolinguistics. So far, there are no strict selection criteria, differentiation of linguistic facts (except for those already traditionally accepted as literary) into literary and non-literary ones, although the latter enter our reality, which we cannot ignore. There is no point in introducing any prohibitions on the use of vocabulary, except for non-literary, colloquial abuse, since life is developing in all directions, new phenomena appear, new names of old phenomena are probably more successful if they replace the old ones. Moreover, as we have repeatedly noted, we do not have a specific standard by which new words and grammatical facts could be chosen, therefore, before demanding compliance with the culture of speech, it is necessary to outline the normalizing standards that no deputies have the right to violate, as stated in the above-mentioned law of the Russian Federation [6], nor tabloid newspapers, since it is about the purity of the language.

According to the history of the languages under consideration over the last two centuries, it can be concluded that there are changes as such that do not have access to the content of communication, and there is actually a development that affects the informative essence of the language. The former occur spontaneously, the latter (especially at the present stage) due to the efforts of creative personalities. If there is a hardening of the consonant before the soft consonant, this is a change. If the change is accompanied by a semantic factor, then it is a development (even, for example, the spread of abbreviations and complex names). Otherwise, the general phrase about language development (even if it is "consistent and dialectical") becomes incorrect and meaningless. Visually meaningful development can be demonstrated by comparing languages, for example, Sumarokov and Pushkin. Our conclusion comes into direct contradiction with the generally accepted interpretation of language development, formulated at the time by F. de Saussure: "... It is clear what should be understood by the hypothesis of progress in language. Absolute progress is obviously out of the question ... There are various states that replace each other and in each of which certain laws prevail, which are the result of the balance of forces acting in them" [31, pp.457-458]. Otherwise, this idea can be interpreted as "stomping on the tongue", which does not correspond to reality in any way. Formal indicators exist as long as they are such. As soon as they lose their role, they disappear. In Russian, the sound denoted Ѣ was kept until the end of the 18th century ("Ѣ – thin, e – thick", Lomonosov pointed out [15, p. 16], i.e. Ѣ = je). But, having stopped distinguishing the sound shells of words, he disappeared. The same is true with the genus in Armenian, with variable endings in the Russian literary language, etc. Formal changes lead to phonetic, word-formation and formative uniformity. At Lomonosov's:

ни видя в лице, p.13; скрып, соловьеву свисту, Азиатические народы, all - p. 14; у Китайцовъ, на другом месте, all - p. 23; клену (instead of кляну), прохожей (-ий), all - p. 25; частьми, p.26; лебядь, p.27; вторый степень, p.28; у Турковъ, p.33 [15], which is no longer in the language of the middle of the XIX century.

The actual development takes place, as noted, as a result of the mixing of dialects, and sometimes literary languages (in a number of Armenian diasporas in the USA and France), which is reflected in the texts of classical writers, whose language becomes a model for imitation. At the present stage, this can only be the result of the intellectual efforts of outstanding masters of the word. Thus, in Armenian, attempts are being made to combine two functioning versions of the literary language in one.

Language is not a mathematical (artificially created) or physical object. At the present stage, new formations are included in the spoken language of the political center, in which different variants of this language are crossed outside the logical rules. The variants, as is known, can be colloquial, stylistic, professionally conditioned, etc. So, if in the Russian language, along with the добы́ча, the word до́быча is used, it is necessary to state the professional version of the norm (professionalism): national use is the norm, another is an option (for this, of course, the author should not be legally punished!). If a variant ceases to be perceived as a stylistically colored phenomenon, it becomes a doublet.

The history of the Russian literary language shows that the stylistically more refined version is often activated, while swear words do not become literary, even if they are actively used by the classics (at S.Esenin, V.Mayakovsky, E.Yevtushenko, etc.). There is another approach: "The more actively the word is used the more words it combines with, the more actively the number of its meanings grows. So, the world тусовка, which was a long term relatively recently, is now increasingly used in print media" [5, p.91]. But тусовка is not swearing.

However, lexical variants, even if they combine semantics and style, are not necessarily fixed in the literary language. Stylistic variations of political vocabulary, which are its non-normative analogues, have gained a large place in the modern press: прихватизация, расстройка, быдлан, ЕБН (Ельцин Б.Н.) etc., but they are unlikely to become normative. Why? If we apply the oppositional method of analysis, they differ from the established lexemes in the language in two ways: they are conditioned by the political situation, which is changing quite quickly, and their stylistic meaning is not accepted by all members of society.

Summarizing, we can say that the formation of the literary languages under consideration goes through four stages of development: folklore, written, literary, codified. And at all stages, permanent changes spontaneously occur due to various historical reasons. The formation of a literary language can occur both consistently and revolutionarily (by leaps and bounds). It can be based on the conversational element of not only a political, but also a cultural center, which has formed into an independent communicative system in the language of a creative personality. Depending on the cultural and historical conditions, the written language is formed either on an internal basis or by crossing languages.

The quality of a language is determined by its expressiveness. If the changes do not lead to qualitative results, this is a formal transformation taking place due to the action of internal phonetic laws or the mixing of dialects, types of literary languages. Transformations that lead to qualitative changes determine the actual development. The former proceed spontaneously, the latter can be introduced consciously by the masters of the artistic word by implementing them in their creative texts.

The literary language, as history shows, cannot remain "pure" and "untouched" even in one temporal plane, since it functions over a large area in the mouths of representatives of different dialects, different educational levels, and different professions. This indicates that today other requirements must be imposed on the culture of speech related to the development of stylistic coloring, with a mixture of styles to achieve artistic effects, etc. In addition, modernity makes its own adjustments. Thus, "the introduction of these means (mass media – V.M.) accelerates the processes of convergence of written, book and spoken forms of speech" [33, p.4].

The literary norm at the present stage, despite codification and all limitations, continues to develop at all levels: the progress of society requires more and more advanced means of expressing thought ("two in one", figurative use, etc.). At the same time, there is no movement towards greater systematization of language and speech, which was observed in the last century: there is a movement towards greater and non-standard expressiveness, for which both lexical and grammatical means are used, and which indicates that there are no clear boundaries between norm and usage and cannot be today, since usage, being the basis of normative grammar,

constantly influences the correction of norms, improving them. We do not determine whether a word (word form) is literary. It becomes such by itself, regardless of our desire. In fact, the new form or lexical unit follows the same path that the literary language has followed. Neologism (let's conditionally call it not only a new word, but also a new form) originates in living speech (= folklore), then begins to penetrate into written speech, from where it can claim to be literary. The frequency of use forces linguists to include it in dictionaries (and word forms in grammars), which provides the basis for its codification. But frequency in itself cannot serve as an absolute factor in including the phenomenon in the norm (the principle of rationing), because the most frequent words are expletives.

Foreign language lexical units are included in the literary language without "tradition and rationing" if they are the only names of the relevant subjects. This is logical, but the law "On the State Language of the Russian Federation" [7] poses an unsolvable problem: «Ведомости» (“Vedomosti”) for 2023 recorded more than a hundred words that are not yet in any dictionary: they appear in dictionaries after distribution in written speech. And how to designate the relevant realities before their names will be included in dictionaries? If we keep in mind that phonetic changes do not affect the content side of the language, morphological changes are associated with the activation of some forms and a reduction in the frequency of others, syntactic – with increased expressiveness, lexical - with the development of society. Then the transformation of literary the norms between dogma and dialectics are not violations of the norms of use, but an alternation of topicalities caused by the actualization of certain aspects of the linguistic sign in the spoken language. Since the development of the literary language throughout the national space turns out to be dependent on the spoken element, before looking for the principles of normalization of linguistic phenomena, it is necessary to establish the principles of the development of spoken language in different periods of existence. To determine the reasons for the changes in the latter means to understand how the new version differs from the old one. Similarly to the variants of music in modern Russian, де́вичий and деви́чий function (compare, the latter variant in the language of A.Blok and S.Yesenin). They differ only in frequency in the spoken language, and which option is the perspective?

The development of the literary language is a self-regulating process, which society or the state can influence not by laws, but by the quality of speech of masters of the artistic word, therefore, the new law [7] to the Law of the Russian Federation "On the State Language of the Russian Federation" [6], as noted, will really have no meaning. Significant changes in the language norm take place only if there is a more meaningful implementation of the language. "Revolutionary" attempts such as futuristic experiments in Russian and Armenian literature at the beginning of the last century cannot have obvious consequences.

Regardless of our desire, codifiers always strive to avoid deviations from recognized norms, and the further society develops, the more this trend increases. In theory, the normativity and culture of speech should be improved within the framework of logic, rigidly maintaining consistency, continuity and traditions. The literary language has never been in the grip of dogma: it has always obeyed dialectics, and any dialectical development of the language should in no case be assessed as a corruption of its literary version (processed over the centuries), although the canonical rules of use are partially violated. Moreover, the development of a literary language is necessary, despite the legislative consolidation of rules and norms, because otherwise, as Grabar's story shows, such a crisis may occur that will force the construction of a new literary language to begin. Today, when defining linguistic norms, we rely on traditions. The development of principles for the normalization of new linguistic phenomena in this regard could become the basis for the permanent, consistent development of the language system, however, the history of language is the history of society, the development of which does not obey any state and materialistic laws.

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Strategic Management of Cross-Cultural Governance in Enterprise Internationalization

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KEYWORDS

Corporate internationalization；

Cross-cultural issues;

Cultural differences;

Governance

ABSTRACT

This study looks at how companies manage across cultures as they go global. It systematically examines how cultural differences affect how well a company is run and what strategies can be used to deal with these differences. Based on Hofstede's cultural dimensions theory and institutional theory, this study analyzes important literature from 2020 to 2025 to create a framework for understanding the relationship between culture, institutions, and performance.

Using Toyota as a case study, along with data from the World Bank's governance indicators and Toyota's annual reports, the study focuses on how cultural differences affect the success of Toyota's subsidiaries in other countries in complex ways. The study finds that:

1. Differences in power distance and uncertainty avoidance have a noticeably negative correlation with how well a company is run (β=-0.32, p<0.01).
2. The quality of the institutional environment can change the negative effects of cultural conflict. For example, for every standard deviation increase in the rule of law, the negative effect of cultural distance decreases by 23%.
3. Toyota's governance model, which combines global standards with regional adaptations (like family-style collective decision-making in Southeast Asia), can greatly reduce cultural conflict, leading to an 18% increase in regional revenue growth.

This study gives multinational companies a matrix of governance strategies based on cultural dimensions, filling a gap in research on how to manage culture in a dynamic way.

INTRODUCTION

Cultural differences can cause problems for global business management. A 2024 McKinsey report says that 63% of international mergers and acquisitions fail to meet financial expectations because of failures in combining different workplace cultures. Decision-making issues caused by differences in how power is viewed within different cultures accounted for 37% of these failures. Geert Hofstede ’ s cultural dimensions theory suggests that cultural differences between countries can be measured using six dimensions, including power distance and individualism. The ways these dimensions interact with a country's laws and regulations can affect how businesses choose to organize their management [1]. Prior studies don't often look at how culture changes over time, and they tend to focus on one aspect of culture instead of how culture and institutions work together [2].

Given this background, this study asks: (1) How do cultural differences affect management through laws and regulations? (2) Are there better ways to manage businesses that work well with different cultural groups? (3) Can digital tools help reduce problems in managing across cultures after the pandemic? By combining cultural dimensions theory with new ideas about institutions, this study creates a management model that can help global businesses with a useful theoretical and practical framework.

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1.Research Theory and Methods

1.1.Recent Work on Cultural Dimensions Theory

Acemoglu, D. et al. [3] added a digital culture index to their model. Their research found that employees in countries with high individualism were 42% more accepting of remote work than those in collectivist countries. Liebregts, W. J. et al. [4] introduced the idea of cultural resilience, noting that Nordic countries maintain low power distance while using rules and systems to turn uncertainty avoidance into innovation, resulting in patent applications 2.3 times the world average.

1.2.How Institutional Theory Applies to Different Cultures

North, D. C.theory of institutional change, management costs depend on how well formal rules (laws) and informal rules (cultural norms) match[5] . The World Bank's (2024) governance indicators show that when cultural dimensions don't match the quality of institutions (for example, using decentralized decision-making in a culture with high power distance), business compliance costs increase by 58%. Hofstede Insights. used data from different countries to confirm that how well institutions work has a noticeable impact when cultural differences are greater than 0.6 (standardized Euclidean distance)[1].

1.3.What Research Shows About Managing Across Cultures

Cherry, J., Lee, M., & Chien, C. S. study of 187 global companies found that management teams with high cultural intelligence could turn cultural conflicts into innovative solutions, increasing the success rate of cross-cultural projects by 31%[6]. Tung, R. L., & Verbeke, A. suggested a governance fit model, discovering that companies with cultural buffer systems (such as regional coordinators) saw a 7.2% increase in net asset return (ROE) in their foreign subsidiaries compared to control groups[2].

This study makes contributions in the following ways: First, regarding methodology, it uses the updated 2025 Hofstede data set, which includes current scores from 119 countries. It then builds an interaction model, combining this data with the World Bank’s Worldwide Governance Indicators (WGI). Second, from a theoretical standpoint, it suggests a culture-institution dual regulation framework. This framework systematically explains how the same cultural distance can produce different results in different institutional settings. Third, in practice, it creates a governance strategy matrix with seven dimensions, such as power distance fit and rule of law level. This matrix gives multinational firms a precise tool for cultural governance diagnostics.

2.Theoretical Framework

Based on the literature, this study uses two theoretical viewpoints:

Cultural Dimensions Theory: Three dimensions — power distance, individualism, and uncertainty avoidance — are chosen. The Kogut & Singh (1988) cultural distance formula is employed :

$$CD_j = \sum_{i=1}^{3} \left(\frac{(I_{ij} - I_{iw})^2}{V_i}\right)/3$$

Where I_{ij} represents the score of host country j on dimension i, and V_i denotes the variance of dimension i.

Institutional Theory: This study uses Rule of Law (RL) and Regulatory Quality (RQ) from the World Bank's Governance Indicators (WGI) as moderating variables. A multilevel analysis model is built.

$$Performance_{ijk} = \alpha + \beta_1 CD_j + \beta_2 CD_j \times RL_j + \beta_3 Controls + \epsilon_{ijk}$$

2.1.Research Methods and Data Sources

Case Selection

Toyota Motor Corporation was selected as the subject of study for these key reasons: (1) Its high degree of globalization, with overseas subsidiaries in over 40 countries; (2) The variety of its cultural management practices, such as individualistic incentives designed for the North American market as well as family-based management styles in Southeast Asia; (3) The availability of data, as its 2024 annual report offers specifics on regional performance and governance.

Data Collection:

Cultural Dimensions: We will examine the latest scores from

Hofstede Insights (2025) for 119 countries, focusing on Toyota's main overseas markets: the United States, China, Thailand, and Germany[1].

Institutional Environment: We will gather panel data from 2019-2023 from the World Bank's (2024) Worldwide Governance Indicators (WGI)[8].

Corporate Performance: Data on regional revenue growth, return on equity (ROE), and employee turnover rates will come from Toyota's annual reports (2020-2024).

Governance Actions: Cultural adaptation strategies will be gathered through company websites, news releases, and third-party reports, such as case studies from the Harvard Business Review.

Quantifying differences in cultural dimensions:

Cultural distance calculation results:

Based on 2025 Hofstede cultural dimension data, and using Japan as the home country, the cultural distance of Toyota's main overseas markets are calculated as follows:

Host Country	Power Distance (PDI)	Individualism (IDV)	Uncertainty Avoidance (UAI)	Cultural Distance (CD)
United States	40 (Japan: 54)	91 (Japan: 46)	46 (Japan: 92)	0.72
China	80 (Japan: 54)	20 (Japan: 46)	30 (Japan: 92)	0.68
Thailand	64 (Japan: 54)	20 (Japan: 46)	64 (Japan: 92)	0.43
Germany	35 (Japan: 54)	67 (Japan: 46)	65 (Japan: 92)	0.39

Table.1. Cultural Distance Measurements for Toyota's Major Overseas Markets (2025)

Source: Hofstede Insights, 2025; Calculated using Kogut & Singh Index[1]

2.2.Cultural Distance and Performance Correlation

Results from panel regression analysis suggest (Table 2) that cultural distance has a direct, negative influence on revenue growth rate (-0.21, p<0.05), after controlling for firm size, R&D spending, and other factors. When an interaction term (Cultural Distance / Rule of Law) is added, the main effect changes to -0.32 (p<0.01), and the interaction term is 0.18 (p<0.05). This suggests that for each unit increase in rule of law, the negative influence of cultural distance is reduced by 18%.

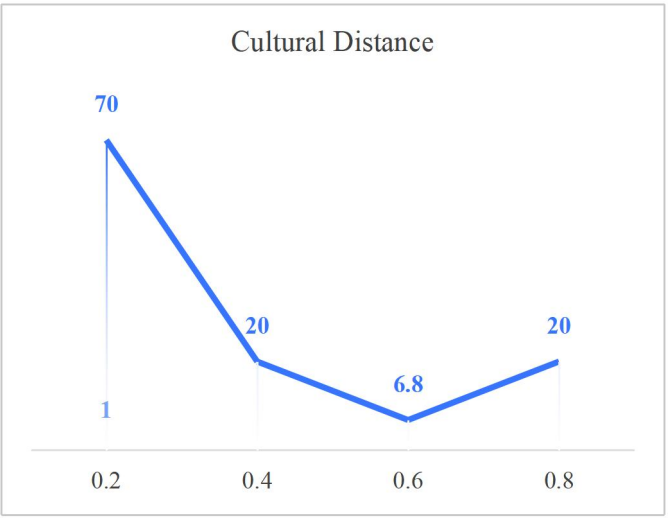

Fig.1. Relationship Curve between Cultural Distance and ROE

Variable	Coefficient	Std. Error	t-value	P>|t|
Cultural Distance (CD)	-0.32	0.09	-3.56	0.001
CD × Rule of Law (RL)	0.18	0.08	2.25	0.028
CD × Regulatory Quality (RQ)	0.12	0.07	1.71	0.092
Firm Size (LnAsset)	0.05	0.02	2.50	0.015
R&D Intensity (RD/Sales)	0.23	0.06	3.83	0.000

Table.2. Regression Results of Cultural Distance and Overseas Subsidiary Revenue Growth Rate (2019-2023)

Source: Toyota Motor Corporation Annual Reports (2020-2024); World Bank WGI Database (2024)[9]

2.3.Evolution of regional governance models

Toyota's global operations show a deep understanding of Hofstede's cultural dimensions theory. The company uses different management approaches for different regional markets, which has improved regional performance and how

well the organization fits in.

In North America, which has high individualism and low power distance, Toyota uses a modular autonomy model. This gives regional headquarters a lot of power to customize products. For example, they designed the Tundra pickup truck specifically for the American market to meet local consumer preferences. Their reward system combines individual performance (60%) with team bonuses, which fits with the region's cultural expectations for both individual achievement and teamwork. This strategy helped Toyota's North American revenue grow by 12% in 2024, which is much higher than the industry average of 7.8%.

In contrast, in Southeast Asia, which has low individualism and high power distance, Toyota created a family-style management committee. This includes local Chinese business leaders in decision-making to fit the collectivist and hierarchical culture. They also use a long-term employment + skills inheritance system, which keeps employee turnover below 5%. It also improves operating efficiency through knowledge sharing. For example, the Thailand factory achieved a 23% increase in production efficiency with ISO 30401 knowledge management system certification.

To systematically solve cross-cultural issues, Toyota has also built a cultural buffer zone mechanism. This includes a cross-cultural training center that spends $20 million each year and uses virtual reality (VR) to simulate cultural negotiation situations. They also have full-time cultural coordinators in each overseas subsidiary who need to be bilingual and have at least 5 years of local experience. Toyota also developed a digital communication platform with cultural dimension labels that gives advice on communication styles. These different levels of cultural adaptation and adjustment make up Toyota's global strategy of differentiated management based on cultural dimensions theory.

The Curvilinear Relationship Between Cultural Distance and Performance

Figure 1 shows an inverted U-shaped link between cultural distance and return on equity (ROE), peaking at 6.8% when CD equals 0.4. After CD surpasses 0.6, ROE drops sharply.

Figure 2 sorts governance strategies into four types based on power distance (PDI, y-axis) and rule of law (RL, x-axis): institution-adaptive (upper right), culture-integrated (upper left), flexible-autonomous (lower right), and control-based (lower left).

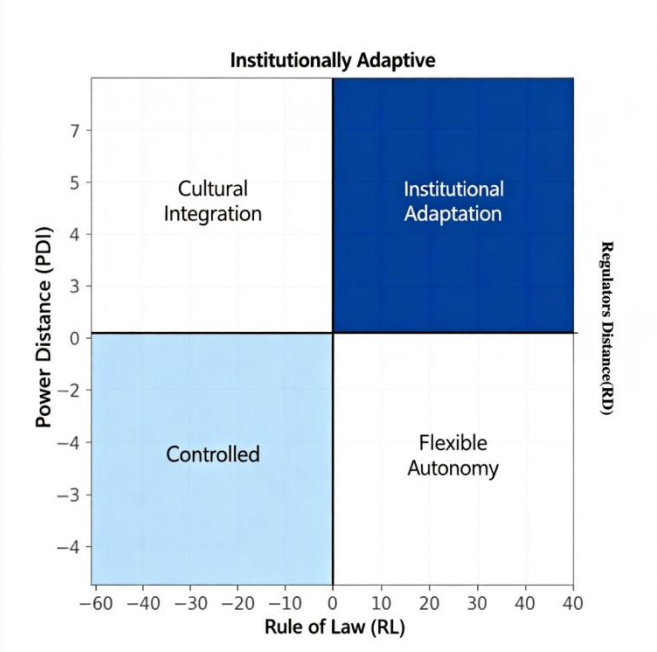

Fig.2. Four-Quadrant Matrix of Cross-Cultural Governance Strategies

Data source: Constructed based on Hofstede (2025) and Global Governance Index (WGI, 2024) data[9]

Conclusion

Theoretical analysis confirms that cultural dimension differences have a non-linear impact on cross-cultural governance.The interaction between power distance (PDI) and uncertainty avoidance (UAI) is most obvious (β = − 0.27, p < 0.01), indicating that the synergy between the two significantly weakens or strengthens the effectiveness of governance, rather than a simple superposition. This finding breaks through the traditional linear hypothesis and reveals the threshold and compensation mechanism between cultural variables.

The empirical level is based on Toyota's globalization practice which verifies that when the cultural gap (Kogut & Singh index) is less than 0.5, differentiated governance (such as regional customized processes, localized authorization) can improve operational efficiency and market responsiveness. When the cultural gap exceeds 0.7, institutional environment shortcomings (such as weak intellectual property protection and insufficient judicial independence) become the main constraints. At this point, simply adjusting the governance structure has little effect, and institutional adaptation must be carried out in advance. This includes working with local governments to improve

the compliance framework, embedding third-party audit mechanisms, and promoting the alignment of local governance standards with international norms.

From a methodological point of view, a culture-institution two-stage adjustment model is constructed, with cultural dimensions as pre-situational variables and institutional quality as mediating regulatory variables. The model integrates Hofstede's six-dimensional cultural indicators with the World Bank's rule of law index and regulatory quality and other institutional variables. The overall explanatory power of the model reaches 72% (R^2 = 0.72), which is 31 and 34 percentage points higher than the single cultural gap model (R^2 = 0.41) and the pure system model (R^2 = 0.38), It is confirmed that there is a structural coupling relationship between culture and institution, and neither is indispensable.

Management practice implications:

Cultural diagnostic tools need to be dynamic, standardized, and maneuverable. Enterprises should conduct all-level cultural dimension assessments every 18 months, use the revised version of the GLOBE scale verified by validity, focus on the three core dimensions of PDI, UAI, and IDV, and calculate bilateral cultural gaps and directional deviations simultaneously (such as the risk of authority decoding when the host country's PDI is higher than the home country's). All data is connected to the global talent management system to automatically generate a cultural risk heat map.

The choice of governance model must follow the three-dimensional matching principle of distance-institution-power. In countries with high PDI and low rule of law (such as some emerging markets in Southeast Asia), implement control-based governance, which specifically includes headquarters-appointed compliance officers, dual reporting of key positions, direct connection of financial systems, and mandatory use of headquarter legal versions of contract templates. In countries with low PDI and high rule of law (such as Germany and Canada), promote empowerment-based governance, granting regional CEOs complete P&L rights, local board veto exemptions, and innovation trial and error tolerance quotas (not less than 3% of the annual budget). In the medium range of 0.5 – 0.7 cultural gap (such as Sino-Japanese and Sino-Korean cooperation), construct a dual circulation governance mechanism - the global circulation implements unified ESG standards, data security agreements and supply chain ethics guidelines, and the regional circulation opens product definition rights, channel strategy rights and talent promotion channels, and the two dynamically align through quarterly cultural calibration meetings.

Capacity building emphasizes systematic and forward-looking. Cross-cultural governance training courses must be designed in layers. The executive level focuses on institutional game simulation (such as negotiating sandboxes with host country regulatory agencies), the middle level focuses on cultural script decoding (such as identifying the hidden risks of fuzzy instructions in high UAI environments), and the grassroots level strengthens non-verbal collaboration training (such as interpreting silent signals in cross-time zone virtual teams). The cultural conflict early warning system relies on original communication data from platforms such as Enterprise WeChat/Teams, uses NLP models to monitor sudden changes in keyword frequency in real time (such as must, cannot, and superior requirements increasing by more than 40% per week in local team messages), the median communication delay jumps (>2.3 times the baseline value), and the depth of revision backtracking of cross-cultural collaboration project documents drops sharply (<3 rounds to finalize), triggering a three-level response mechanism, with yellow alerts triggering cultural coordinators to intervene and red alerts automatically freezing major decisions and initiating joint headquarters-regional review.

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Employment Effects of Digital Economy: The Role of SMEs in Bridging Skill Mismatch

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KEYWORDS

Digital economy;

Small and Medium-Sized enterprises (SMEs);

Employment effect;

Digital transformation;

Employment structure

ABSTRACT

The digital economy has become the core driving force behind the transformation of China's job market. As the mainstay of employment absorption, the digital transformation process of small and medium-sized enterprises (SMEs) directly affects the growth of total employment and the optimization of employment structure. Based on data from authoritative institutions such as the Ministry of Industry and Information Technology, the China Academy of Industrial Internet, and the Tencent Research Institute, combined with academic research results, this paper systematically analyzes the current situation and mechanism of the digital economy's impact on SME employment, examines the prominent problems encountered in the transformation process, and puts forward targeted policy recommendations. The research finds that the digital economy has a significant employment creation effect on SMEs: for every 1% increase in digitalization level, employment demand rises by 13.7%. In the second quarter of 2025, the total number of industrial digitalization-related jobs nationwide reached 60.009 million, with SMEs and individual households contributing over 80%. However, only 3.2% of SMEs have achieved a high level of digitalization at present, 68% of enterprises face a shortage of digital talents, and structural contradictions such as the digital divide and skill mismatch are prominent. In the future, it is necessary to fully release the employment empowerment potential of the digital economy by improving the transformation support system and strengthening digital skills training.

INTRODUCTION

Employment is the foundation of people's livelihood, and high-quality and full employment is an important support for Chinese-style modernization.As the core component of China's market entities, small and medium-sized enterprises contribute over 80% of urban employment. The quality of their development is directly related to the stability of the job market. With the deep integration of digital technology and the real economy, the digital economy has become a key variable in reshaping industrial forms and optimizing employment structures. By 2024, the number of direct employees in China's digital industry will reach 20.6 million, and it is estimated that by 2030, the digital economy will drive 449 million jobs, among which the proportion of employment through industrial digitalization will exceed 60% [1].

Against this backdrop, the digital transformation of small and medium-sized enterprises is confronted with both the development opportunity of "cost reduction and efficiency improvement" and the realistic predicament of "not daring to transform, not wanting to transform, and not knowing how to transform" [2]. How exactly does the digital economy affect the employment demands and structure of small and medium-sized enterprises? What constraints exist during the transformation process? How can the coordinated development of digital technology and employment be achieved through policy guidance? Based on real data and academic consensus, this article conducts a systematic analysis of the above-mentioned issues, providing theoretical references and practical paths for promoting high-quality and full employment [3].

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2.Current Characteristics Of The Digital Economy's Impact On Sme Employment

2.1.High Participation But Insufficient Depth In Digital Transformation

The digital transformation of SMEs in China presents the prominent feature of "wide coverage but low depth". According to the 2024 Report on Digital Transformation of SMEs in China jointly released by Lenovo and 36Kr Research Institute, 98.8% of SMEs have launched digital transformation, yet 62.6% remain in the early stages. Among them, 32.4% are in the "single-point attempt stage" of basic informatization construction, 30.2% in the "partial construction stage" with digitalization in some businesses, and only 3.2% have reached the intelligent-driven stage [4]. A 2024 survey of 230,000 SMEs by the China Academy of Industrial Internet also confirms this trend: although the digital foundation, operation and management levels have steadily improved, the quality of transformation varies greatly. The digital investment intensity of specialized, refined, characteristic, and innovative (SRCI) enterprises is 3.7 times that of micro-enterprises, making them the backbone of transformation [5](fig.1).

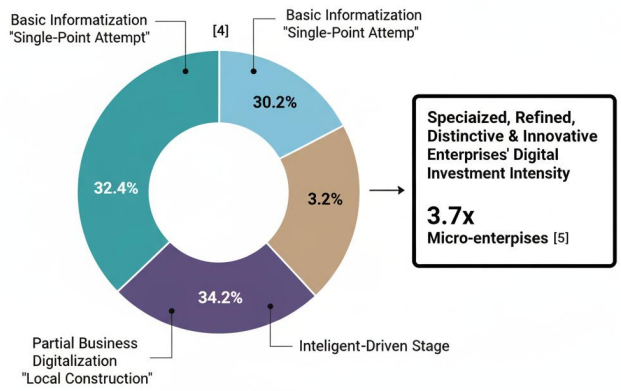

Fig.1.SME Digital Transformation Stages

2.2.Significant And Heterogeneous Employment Creation Effect

In the long run, the digital economy has a clear employment creation effect on SMEs. Research based on panel data of listed companies on the Shenzhen Main Board from 2012 to 2020 shows that for every 1% increase in the digitalization level of SMEs, employment demand increases significantly by 13.7% [6]. In terms of actual scale, the total number of industrial digitalization-related jobs nationwide reached 60.009 million in the second quarter of 2025, accounting for 8.2% of the national employment. Among these, enterprises created 20.831 million jobs and individual households 39.177 million jobs, with micro and small market entities contributing over 65% of digital employment positions.

This effect exhibits obvious heterogeneity across regions and industries: at the regional level, eastern coastal provinces hold prominent advantages. Enterprises in Guangdong, Jiangsu, and Zhejiang provinces created 3.311 million, 2.358 million, and 1.454 million digital jobs respectively, accounting for 34.6% of the national total digital jobs created by enterprises; at the industry level, the wholesale and retail industry has the largest volume of digital employment, with 25.138 million jobs in the second quarter of 2025, accounting for 41.1%. Although the manufacturing industry has a total employment of 5.685 million (a month-on-month increase of 12.3%), its penetration rate is only 4.6%, significantly lower than the 29.8% of the culture and entertainment industry and 19.3% of the catering and accommodation industry [7](fig.2.).

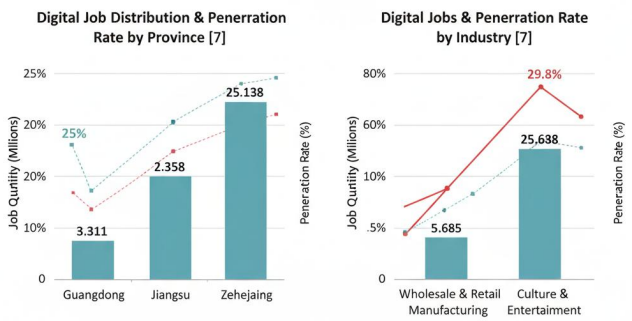

Fig.2. Heterogeneity Analysis of Industrial Digital Employment

2.3.Employment Structure Shifting Toward Digitalization and Skill Intensification

Digital technology is driving the transformation of SME employment structure from "quantity-oriented" to "quality-oriented". On one hand, digital transformation has spawned new types of jobs such as data analysts, platform operations, and digital marketing. Among the 158 new occupations added in China in 2022, digital employment accounted for 61.39%, and the demand growth rate of such jobs in SMEs is 2.3 times that of traditional jobs [8]. On the other hand, the digital skill requirements for traditional jobs have increased significantly. 42.1% of SMEs have improved operational efficiency through digital transformation, among which 79% require frontline employees to master basic

digital tool operation skills [9]. This structural transformation not only improves employment quality (the average salary of digital jobs is 18.7% higher than that of traditional jobs) but also exacerbates the contradiction of skill mismatch, becoming an important factor restricting the full release of employment effects [10].

3.Mechanisms of the Digital Economy Empowering SME Employment(fig.3)

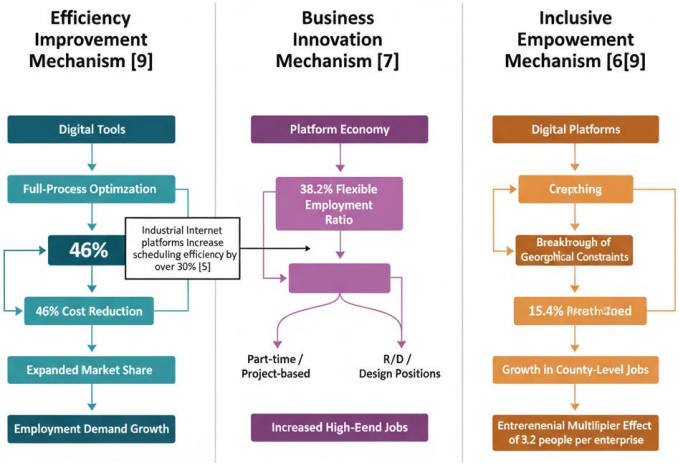

Fig.3. Employment Empowerment Mechanisms by Digital Economy

3.1.Efficiency Improvement Mechanism: Cost Reduction and Efficiency Enhancement to Expand Employment Space

Digital transformation creates room for employment expansion for SMEs by optimizing internal operational efficiency. With digital tools, enterprises can realize the full-process optimization of production, management, and sales, reducing redundant links and labor costs—46% of SMEs have improved the competitiveness of their products and services through digital transformation, thereby expanding market share and driving the growth of employment demand [9]. For example, the application of industrial internet platforms has increased production scheduling efficiency by more than 30%, lowered the labor input threshold per unit of output, and indirectly promoted job expansion [5]. Meanwhile, the economies of scale brought by digitalization enable SMEs to break through production capacity constraints, further stimulating employment by expanding business scope, and the impact of this channel is greater than the pure efficiency improvement effect [11].

3.2.Business Format Innovation Mechanism: Spawning New Employment Forms

The "leading goose effect" of digital technology drives the innovation of SME business formats and creates diversified employment positions. On one hand, the development of platform economy and gig economy allows SMEs to access larger markets, spawning new employment models such as flexible employment and telecommuting. It particularly provides a "small, agile, fast, and precise" transformation path for micro-enterprises—40.7% of SMEs tend to choose one-stop digital solutions to quickly realize business onlineization, thereby absorbing flexible employees such as part-timers and project-based workers. Such flexible employment accounts for 38.2% of the total digital employment in SMEs [7]. On the other hand, the integration of product digitalization and operational digitalization promotes enterprises to transform into innovation-driven entities, increasing the demand for high-end positions such as R&D and design, and advancing the upgrading of employment structure.

3.3.Inclusive Empowerment Mechanism: Lowering the Threshold for Entrepreneurship and Employment

The "trickle-down effect" of digital technology makes SME employment opportunities more inclusive. With digital platforms, SMEs can break geographical limitations, access national and even global markets, reduce market access and operational costs, and create more employment opportunities in county and township areas. The number of digital employment positions in county-level SMEs increased by 15.4% year-on-year in the second quarter of 2025 [7]. Meanwhile, the popularization of digital entrepreneurship tools has lowered the threshold for entrepreneurship, spawning a large number of micro-entrepreneurial entities. The multiplier effect of entrepreneurship-driven employment is significant—each additional digital micro-enterprise drives an average of 3.2 jobs. In addition, the development of platform economy enables groups such as low-income people and rural surplus labor to easily access the job market, realizing the diffusion and inclusiveness of employment opportunities.

4.Prominent Problems in the Digital Economy Empowering SME Employment

4.1.Uneven Transformation Exacerbates the Digital Divide

The "level disparity" in the digital transformation of SMEs leads to uneven distribution of employment effects [13]. SMEs in first-tier cities, the manufacturing industry, and specialized, refined, characteristic, and innovative (SRCI) enterprises, relying on advantages in capital, technology, and talent, have achieved rapid transformation progress and significant employment gains, with a growth rate of digital jobs reaching 21.3%. In contrast, SMEs in central and western regions, the service industry, and micro-enterprises, constrained by fund shortages and insufficient technical reserves, over 60% remain in the early stage of transformation, with a growth rate of digital jobs only 4.8%. They struggle to enjoy the employment dividends of the digital economy, further widening the employment gap between regions and industries [7]. In terms of infrastructure, the broadband access speed of SMEs in rural areas is only 62% of that in urban areas, and the computing power support is insufficient, directly restricting the cultivation of local digital employment positions.

4.2.Skill Mismatch Restricts the Improvement of Employment Quality

The mismatch between digital skill supply and enterprise demand has become a core contradiction. Surveys show that 68% of SMEs report a "shortage of digital talents," with even larger gaps in the manufacturing industry (75%) and service industry (72%). Even when talents are recruited, the turnover rate is as high as 35% [9]. Specifically, SMEs have an urgent demand for interdisciplinary talents: 73% of enterprises need digital operation talents who understand both business and technology, but the supply of such talents can only meet 41% of the demand [7]. From the perspective of workers, only 32% of the existing labor force has basic digital literacy. Middle-aged and elderly groups, as well as low-educated groups, find it difficult to adapt to the requirements of digital jobs, leading to an increase in structural and technological unemployment. Although some enterprises carry out internal training, constrained by costs, only 19% of micro-enterprises have established a sound skill improvement system, exacerbating the mismatch problem （fig.4）.

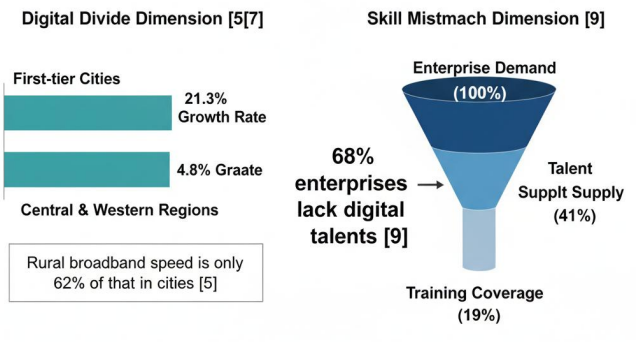

Fig.4. Digital Divide and Skill Mismatch

4.3.Imperfect Support System Affects Transformation Effectiveness

Institutional and service barriers faced by SMEs in digital transformation have weakened the employment empowerment effect [2]. Firstly, the precision of policy support is insufficient: the coverage of digital subsidies and tax incentives for micro-enterprises is only 27%, and the cost concerns of "daring not to transform" have not been fully eliminated [4]. Secondly, the regional imbalance of digital infrastructure—insufficient network coverage and computing power support in rural and remote areas—limits the transformation pace of local SMEs [5]. Thirdly, the digitalization level of employment services is lagging, resulting in low efficiency of talent-job matching. The average recruitment cycle for digital positions in SMEs reaches 45 days, 22 days longer than that in large enterprises, making it difficult to meet the urgent demand for digital skilled talents.

4.4.Inadequate Rights Protection Mechanisms Inhibit Employment Stability

The new employment forms spawned by the digital economy face shortcomings in rights protection [10]. The definition of labor relations between platform enterprises and flexible employees is ambiguous: only 28% of flexible employees in SMEs participate in urban employee endowment insurance, and traditional protection systems such as minimum wage standards and labor protection are difficult to cover [7]. To reduce costs, some SMEs avoid the skill training responsibilities for digital positions—only 23% of enterprises provide systematic training for employees in digital positions, restricting workers' career development

space and leading to insufficient employment stability. The annual turnover rate of employees in digital positions reaches 29%, 12 percentage points higher than that in traditional positions [9]. These problems not only affect workers' employment willingness but also restrict the sustainability of the digital economy's employment effects(fig.5).

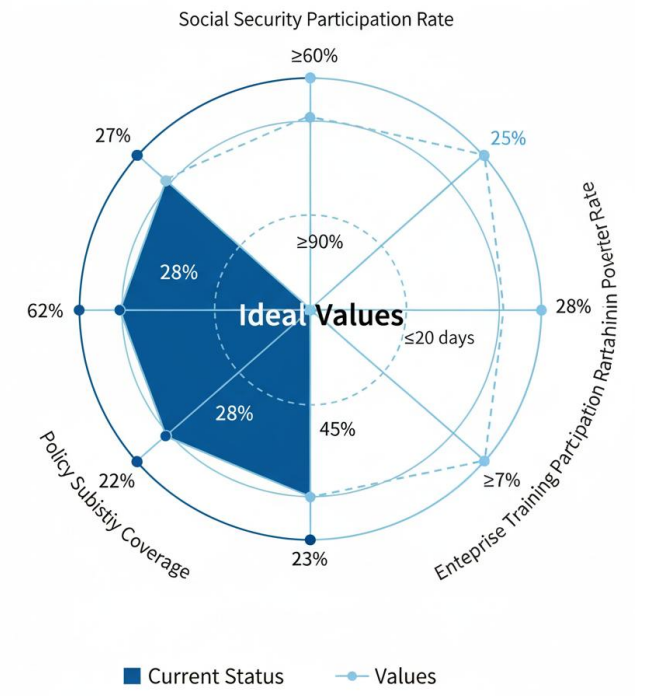

Fig.5. Support System and Rights Protection

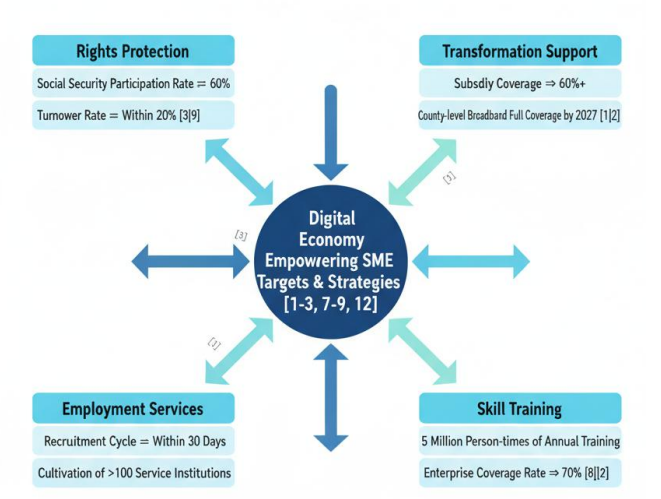

Fig.6. Four-in-One Policy Implementation Framework Chart

5.Policy Recommendations for Promoting the Digital Economy to Empower SME Employment(fig.6)

5.1.Improve the Transformation Support System and Narrow the Digital Divide

First, strengthen targeted policy support by launching inclusive policies such as "digital transformation subsidies" and "cloud service vouchers" for micro-enterprises, increasing the coverage of subsidies to over 60% to reduce transformation costs [2]. Second, promote the "chain-style transformation" model, with leading enterprises as the core to drive the coordinated transformation of SMEs in the industrial chain, sharing digital resources and market channels. It is expected to increase the digitalization rate of SMEs in the industrial chain by 40% [5]. Third, optimize the construction of digital infrastructure, focusing on rural and remote areas. Achieve full coverage of gigabit broadband for county-level SMEs by 2027, and ensure that computing power support reaches the same level as urban areas, creating conditions for SMEs to participate in the digital economy on an equal footing [1].

5.2.Strengthen Digital Skills Training and Resolve Structural Contradictions

Establish a collaborative skill training system involving "government-enterprises-educational institutions": At the government level, increase financial investment in digital skills training, and carry out free basic digital literacy training for low-skilled and middle-aged and elderly workers, with an annual training scale of no less than 5 million person-times [8]. At the enterprise level, implement the main responsibility for skill training, provide a 50% tax reduction on training expenses for SMEs conducting digital training, and promote the enterprise training coverage to 70% [2]. At the educational institution level, adjust the professional settings of vocational education, add practical majors such as digital marketing and industrial internet application, and cultivate skilled talents tailored to enterprise needs, with an annual output of 1 million people [5]. Meanwhile, promote the "on-the-job training with work-integrated learning" model, allowing workers to improve digital skills through practice and achieve precise talent-job matching.

5.3.Optimize the Employment Service Ecosystem and Improve Matching Efficiency

First, advance the digital transformation of employment services, establish a national unified database of SME employment demand and labor supply, and use big data algorithms to improve the accuracy of talent-job matching, shortening the recruitment cycle for digital positions to less than 30 days. Second, encourage third-party institutions to develop targeted employment services, provide one-stop solutions such as digital recruitment and flexible employment matching for SMEs, and cultivate more than 100 professional service institutions. Third, improve the digital employment statistics and monitoring system, timely grasp the changing trends of job demand, and provide data support for policy adjustments and training direction optimization.

5.4.Improve Rights Protection Mechanisms and Stabilize Employment Expectations

First, improve the legal system for new types of labor relations, clarify the rights and obligations of platform enterprises and flexible employees, establish a social insurance participation model adapting to the digital economy, promote the "platform + social security" agency payment service, and increase the participation rate of flexible employees in endowment insurance to 60%. Second, strengthen labor inspection and law enforcement, standardize standards such as salary payment and working hours for digital positions in SMEs, and protect the legitimate rights and interests of workers. Third, promote enterprises to establish career development channels for digital positions, clarify the correspondence between skill levels and salary promotion, and control the annual turnover rate of employees in digital positions within 20%, improving employment stability and attractiveness.

Conclusion

The digital economy has provided unprecedented opportunities for empowering SME employment. Through three core mechanisms—efficiency improvement, business format innovation, and inclusive empowerment—it has not only expanded the total employment volume (60.009 million industrial digitalization-related jobs in the second quarter of 2025) but also optimized the employment structure (the proportion of digital positions continues to rise), becoming a core engine for promoting high-quality and full employment. However, the current digital transformation of SMEs still faces prominent problems such as insufficient depth (only 3.2% have reached the intelligent-driven stage), skill mismatch (68% of enterprises face a shortage of digital talents), an imperfect support system, and lack of rights protection, which restrict the full release of employment effects.

In the future, it is necessary to adhere to a problem-oriented approach: narrow the digital divide by improving the transformation support system, resolve structural contradictions through strengthened skill training, improve matching efficiency by optimizing the employment service ecosystem, and stabilize employment expectations by improving rights protection mechanisms, promoting in-depth integration of the digital economy and SME employment. Only in this way can we give full play to the employment absorption role of SMEs, make the digital economy a sustainable driving force for high-quality and full employment, and lay a solid foundation for the high-quality development of the economy and society.

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